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Preface

This Working Paper is based on a MSc (Forestry) thesis: Jan Fischer (2004): *Sustitutes or Complements? How tropical and non-tropical wood products compete.* Danish Centre for Forest, Landscape and Planning, KVL.

Abstract

Measures of substitutability are rarely applied to the analyses of the international trade in wood products. The elasticity of substitution measures how a ratio of factor inputs responds to a change of the ratio of factor input prices. This way the elasticity of substitution provides information that differs from own-price and cross-price elasticities, viz. it measures how factor inputs compete.

The study encompasses 1962-2001 time-series for six countries with a major production and consumption of wood products. Data is a merger of trade flow data from the European Forest Institute and production data from FAOSTAT. The analytical framework is the Translog cost function with homogeneity and symmetry imposed. Wood products are represented as aggregates of roundwood, sawn-wood, panels, pulp and paper. Each aggregate is represented by tropical and non-tropical origin, which produces a demand system of ten equations. Between each of the aggregates, substitution elasticities are computed in terms of Morishima and McFadden's measures. The elasticities are employed to conclude on how the tropical countries may increase their revenues from the exports of wood products. Finally, the question of the elasticities being constant over time is addressed.

In terms of McFadden's measure, the analysis finds that the substitutability increases with the level of value added. By application of Morishima's measure, it is made clear that the substitutability is more sensitive to changes in the tropical prices than the non-tropical prices. These findings imply that down-stream processing may be a stable path to increased export earnings, if the tropical producers are able to improve their competitiveness in terms of prices. The study finds that the degree of substitutability varies across countries and in some instances the elasticities vary systematically over time. The first imply that elasticity measures of one country should not be transferred to the analysis of other countries. The second imply that the substitution elasticities should be introduced into projection by a functional form to avoid systematic errors.

Keywords: *Substitution of elasticity, wood products trade*.

Contents

1 Introduction

1.1 Background

This study addresses how tropical and non-tropical wood products compete. In many cases tropical origin is synonymous with developing country origin, which is interesting in two respects: A trade regulation perspective and a resource utilisation perspective. In the case of trade, a group of developed countries in the Northern Hemisphere are the major buyers of the tropical wood based products that enter the international trade. This makes the international trade in tropical wood products an important source of 'hard' foreign exchange to many developing countries. At the same time, wood products trade is regulated via tariffs and other measures that will be subjects to change for many years onwards. The current trade regulations are asymmetric, and therefore it is almost inevitable that trade liberalisations will affect trade in asymmetric ways, e.g. by affecting relative prices. In the appraisal of such changes knowledge about substitutability may prove very useful.

In terms of resource utilisation there are striking differences between the temperate and tropical regions. At the end of the 1990s approximately 3.5 billion cubic metres were removed from the forests worldwide, of which the temperate regions accounted for a little more than the tropics. However, the purpose of the felling differs significantly. By 1995 the production of industrial wood in the developed regions was almost three times that of the developing countries, leaving the latter part with fuelwood as the primary product. Fuelwood is for the most part consumed domestically, and as a result tropical wood products make up a very small part of the international timber trade, approx. 11 percent by value in 1990. So even though there might be good reasons for the modest role of tropical wood products on the international scene, there should be no doubt that the tropical forests hold an unexploited potential for increased export earnings. This is further backed by the facts that much tropical logging is extremely selective (many species are not even traded) and that the growth increment in many tropical regions may exceed that of the temperate forest many times. However, realisation of such competitive advantages may rely upon knowledge about the substitutability of the different origins of wood. Furthermore, the issue of who processes the 'raw wood' into value added products is paramount to the level of benefits from trade and to the usage of the labour endowments. It is common knowledge that many developing countries suffer from high unemployment rates and as a consequence would benefit from moving the processing further 'down stream'. The evaluation of such possibilities may be supported by knowledge about the substitution between wood products of different processing orders, cf. Barbier *et al.* (1994), Peck (2001).

In 1932 the famous economist Sir John R. Hicks (1904-1989) introduced the concept of the elasticity of substitution as a measure of the ease with which capital and labour substitute. Since then, the elasticity of substitution has become a central issue in economics. The elasticity of substitution tells us how a ratio of factor inputs changes as the slope of the corresponding isoquant changes. Therefore, the elasticity of substitution is a measure of the *curvature* of the isoquant, which tells us a good deal about the technology of a given economic setting. Hicks' technology was designed to measure two-factor substitution only, and therefore a number of generalisations to more factors have been developed. Allen, Morishima and McFadden's measures are prominent examples. These measures are closely related but they measure substitutability in different ways and produce different outcomes.

The elasticity of substitution can be interpreted as a measure of *competition* between a given set of factors. In case of a 'high' elasticity of substitution the factor inputs easily substitute and therefore compete, and vice versa in case of a 'low' elasticity of substitution. It is a paradigm of the international economic theory that it requires two things to realise welfare gains from trade liberalisations: A distortion of the trade and the existence of substitutability. For this reason the elasticity of substitution is particularly relevant for policy applications. The elasticity of substitution allows for the understanding of how regulatory measures like taxes, tariffs and subsidies may affect the usage of factor inputs. However, despite its importance, the elasticity of substitution is seldom employed in the analysis of how wood products substitute, instead the application of own-price and cross-price elasticities seems to be more popular. The latter two express the impact of a price change of one factor to the usage of either the same factor or another factor, and it follows that they do not measure substitutability between pairs of factors. Besides this, substitution elasticities are most commonly computed as means over time, which implies the assumption that the substitutability is constant. This is probably due to simplicity, but it cannot be taken for granted that the assumption is valid, cf. Barbier (1996), Debertin (1986), Varian (1992).

In sum, there are good reasons to dwell on the understanding of how tropical and non-tropical wood products compete, and this brings focus on the application of the elasticity of substitution or lack of the same. In the field of wood products research, knowledge about such substitution is very limited. The number of studies that address the issue are few, and when the issue is addressed, the studies are either specific with respect to country, commodities or both. This is the point of departure for the study.

1.2 Study objective

The purpose of this study is to bring new insight into how tropical and non-tropical wood products compete. Competition will be expressed in terms of substitution elasticities and the study will address substitution between the major timber grades as well as pulp and paper. Substitution elasticities will be measured in two ways, viz. between tropical and non-tropical wood products with similar and different degrees of processing. Moreover, the study attempts to capture some of the variation across the major wood consuming countries, and therefore the approach is multilateral. The substitution elasticities will be employed to conclude on two perspectives of the tropical countries. First, how the foreign exchange earnings from wood product exports may be increased, and second, how the tropical countries are affected by tariff reductions. Furthermore, the implications of applying the different measures of substitution and the widespread assumption that the elasticities are constant over time will be assessed.

2 Methods and materials

This chapter presents the methodological framework of the study. The first section addresses the literature; the second section deals with econometrics, and the third section elaborates on the concept of the Elasticity of Substitution. The fourth section presents the applied data, the data sources and how raw data are treated to fit the model requirements. Finally, the fifth section addresses the delimitations of the analysis and the interpretation and application of the outcome.

2.1 Literature

The applied literature can be divided into four parts. One part concerns the current knowledge on the application of substitution elasticities within wood products research, a second part that deals with production and micro economics, a third part that addresses applied econometrics and a fourth part on international economics.

Within wood products research, application of the elasticity of substitution is close to non-existent. For this reason the methodology concerning literature becomes a question of getting the most out of the available, instead of isolating the best and the most relevant literature. Upon a comprehensive search of the databases CAB, AGRIS and AGRICOLA with extensive use of the Thesaurus, nine papers were identified of which seven seemed relevant. Of these seven the library failed to take home one. Going through the references identified one more study that was brought about. Of these seven papers none address the elasticity of substitution specifically, instead four studies apply own and/or cross price elasticities in the analysis of substitution. The library kept one book that quotes two relevant substitution elasticities from a 1988-study – without stating how the elasticities were measured. Unfortunately, the library failed to take the underlying paper home. It should be evident that the literature provides limited room for constructing a set of references or expectations for the evaluation of the outcome of the analysis. However, a few useful results can be derived from the literature and these are presented in Section 3.4. The literature search strategy is presented in Appendix F.

Many textbooks on micro-/production economics address the elasticity of substitution in the two-factor case, but very few address the generalisation to more than two factors. However, a good share of references are given to Chamber's (1994) textbook on applied production economics, and this seems to be for good reasons. Chambers provides a thorough introduction to the elasticity of substitution, how to generalise it to more than two factors and a presentation of a range of different measures of the elasticity of substitution. Even though it is ten years old, Chamber’s textbook is believed to be one of the most up-to-date on the issue and is therefore applied as a central reference in this study. The other parts of micro-/production economics rely on the textbooks by Debertin (1986) and Varian (1992), which provide careful analysis of many issues. The library at Copenhagen Business School provided some of the most recent articles that are published on the elasticity of substitution in general, and two working papers were found by Google search on the Internet. Going through the references led to circulation and therefore the search for more papers ended.

The literature on econometrics is vast and ranges from the strict theoretical analysis to the applied form. Since the study emphasises a proper analysis of a specific data set and not a theoretical discussion, the materials by Jensen (2003), Jensen & Toftkær (2002), Jensen & Wegge (2002) and Otto (1998) are the primary sources. These materials are compact with respect to theory and provide good examples of how to do the analysis with the SAS package, although they are certainly not ‘cook books’. Moreover, the textbook by Greene (2003) has been used as an additional source.

The international economic theory is represented by parts of the materials that are applied at the corresponding course at KVL.

2.2 Econometrics

2.2.1 The choice of functional form

An econometric analysis assumes a mathematical-technical relation between dependent and explanatory variables. In the following this relation will be termed *functional form* or sometimes *model*. The choice of a functional form is synonymous with controlling what information data are allowed to give. At the same time data availability sets limits to the models to choose from and the questions to be answered. Therefore convergence between the purpose, the choice of model and data is central to the outcome of the analysis. The following text on choice of functional form is based on Chambers (1994), Jensen & Toftkær (2002), Jensen & Wegge (2002), Otto (1998).

This study relies on international trade statistics for three reasons. Trade statistics are relatively easy to access; they contribute with many observations due to their long history, and finally the nomenclature is fairly even across countries and therefore data are comparable. However, within wood products, the international trade statistics have two important characteristics. First, the data concern goods that for the most part are intermediate goods, which will be processed further into final goods. Second, prices are import prices measured by the customs authorities at the national borders. These characteristics imply that data are not suitable for modelling end-consumer behaviour. Instead, the analysis considers each of the importing countries as a producing agent, which processes the intermediate products further and responds to the import prices as if they were production factor input prices. Therefore, the analytical framework is modelling of *demand* for factor inputs, and for this purpose a cost function approach is employed. A cost function assumes cost minimisation, and this is known as a model of the *dual approach* to the problem of utility maximisation. The dual approach is common for modelling demand, because the primal approach requires knowledge about the underlying utility function, which is difficult to access. The cost function must exhibit the following properties to be consistent with the assumption of utility maximisation: Homogenous of degree one (if all prices double, costs must double for utility to be maintained), increasing in prices (a price increase for one good incurs a similar cost increase for utility to be unchanged) and concave in prices (cost increases linearly with prices, at the most). Furthermore, the cost function must be twice continuous differentiable in the arguments, which implies that no discrete jumps in the structure are allowed. Therefore, the applied model or functional form must be homogenous, increasing and concave in prices and twice continuous differentiable in the relevant area.

The purpose of the analysis is to explore substitution elasticities with respect to how they might vary between goods, countries and over time. Estimation of non-constant substitution elasticities rules out the array of economic models that assume none or constant elasticity of substitution, e.g. Leontief, Cobb-Douglas or the Constant elasticity of substitution function (CES). Relevant models therefore belong to the group known as flexible functional forms, which a priori place few restrictions on the technology. The Generalised Leontief, the Transcendental Logarithmic (Translog) and the Almost Ideal Demand System (AIDS) are widely used flexible forms, which also may be homogenous, increasing and concave in prices and twice continuous differentiable. The AIDS is designed to model end-consumer behaviour and therefore it is not a natural starting point. The Generalised Leontief is often well behaved when substitution is low and as a result models well when the factors are close to being complements. Compared to the Generalised Leontief the Translog may perform better at higher levels of substitution. Since the analysis can be expected to find low as well as higher levels of substitution the Translog cost function will be the starting point.

2.2.2 The Translog cost function

The application of the Translog cost function follows a multi-stage approach, which is common for the structure of demand systems, e.g. Jensen & Toftkær (2002) and Uusivuori & Kuuluvainen (2002). Consider, as the first stage, an underlying production function for the wood using industries of each country

(1) $$Y = F(W, L, K, E)$$

where Y denotes gross output and W, L, K, E denote aggregate inputs of wood, labour, capital and energy. Assuming cost-minimising behaviour (1) can be represented as the cost function

$$C = g(P^W, P^L, P^K, P^E, Y) \tag{2}$$

where C is total cost of production and P^i = $W, L, K, E,$ are input prices of the aggregates. Supposing that the national industry will choose the mix of wood types that will minimise the cost of the wood aggregate, and by assuming a homothetically separable production technology, (1) can be written as

$$Y = F[W(x_1, x_2, ..., x_i), L, K, E] \tag{3}$$

where W is a homothetic sub-production function describing the industries' wood consumption of the wood sub-aggregates $x_1, ...x_i$. The resulting, second stage or sub-cost function for the input of wood is

$$C^W = h(p_1, p_2, ..., p_i) \tag{4}$$

where p_i denotes the prices of different wood types. The primary gain from the multi-stage approach, under the assumptions of homothetic separability, is that the cost equations of the wood types can be estimated independently of the non-wood inputs. This saves degrees of freedom.

By Shephard's lemma, a system of demand equations, in terms of cost shares, can be derived. Shephard's lemma states that if $C(p,y)$ minimises total cost of production, then the cost minimising set of factor demands is given by

$$x_i^* = \frac{\partial C(p, y)}{\partial p_i} = \frac{Y \partial c(p)}{\partial p_i}, \tag{5}$$

which by differentiating logarithmically yields the cost-minimising factor cost shares

$$s_i = \frac{\partial \ln C(p, y)}{\partial \ln p_i} = \frac{p_i x_i}{C}. \tag{6}$$

The Translog cost function takes the form

$$\ln c(p, y) = \alpha_o + \sum_{i=1}^{k} \delta_i \ln p_i + \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \delta_{ij} \ln p_i \ln p_j + \ln y, \tag{7}$$

which is not linear in the parameters or input prices, but the derived factor shares are. The Translog requires the following restrictions on the parameters

$$(8) \qquad \sum_{i=1}^{k} \delta_i = 1, \quad \sum_{i=1}^{k} \delta_{ij} = \sum_{j=1}^{k} \delta_{ij} = 0 \quad \text{and} \quad \delta_{ij} = \delta_{ji} \quad \text{for} \quad i \neq j\,.$$

Under these restrictions the Translog is homogeneous of degree zero in prices and symmetric in the parameters. Homogeneous of degree zero in prices implies that only relative prices matter. From (6) and (7) the cost share equations are now given as

$$(9) \qquad s_i = \alpha_i + \sum_{j=1}^{k} \delta_{ij} \ln p_j \quad i=1,...,k,$$

where the cost shares sum to unity, which is known as adding up. Homogeneity of degree zero follows from adding up. From (9) follows the system of equations to be estimated empirically (with symmetry imposed)

$$(10) \qquad \begin{aligned} s_1 &= \alpha_1 + \delta_{11} \ln p_1 + \delta_{12} \ln p_2 + \delta_{13} \ln p_3 + \cdots + \delta_{1k} \ln p_k \\ s_2 &= \alpha_2 + \delta_{12} \ln p_1 + \delta_{22} \ln p_2 + \delta_{23} \ln p_3 + \cdots + \delta_{2k} \ln p_k \\ &\vdots \\ s_k &= \alpha_k + \delta_{1k} \ln p_1 + \delta_{2k} \ln p_2 + \delta_{3k} \ln p_3 + \cdots + \delta_{kk} \ln p_k\,. \end{aligned}$$

The equations share variables and parameters and therefore the equations and error terms are correlated, which implies that the conditions for estimation by ordinary least squares (OLS) are not fulfilled. Instead the system is estimated by feasible generalised least squares (FGLS), also known as iterated seemingly unrelated regression (ITSUR). By FGLS the disturbance of each equation is estimated by OLS at first, and then the disturbance-covariance matrix (W) of the system is computed by the OLS residuals. Finally, the parameters are estimated repeatedly until W does not change between the steps. It follows from (8) that W becomes singular (rows or columns are combinations of others) if not one equation is dropped from the estimation. Estimation by ITSUR provides invariance of the parameters with respect to which equation will be dropped.

2.2.3 Sensitivity analysis

An assessment of the regressions and the elasticities should consider the underlying assumptions about the functional form. Basically, the Translog models a logarithmic relation between prices and cost shares. The outcome of applying a different functional form will indicate if the elasticities are sensitive here upon. Another common way is to test a static model vs. a dynamic model, which implies taking time into consideration. This could be done by extending the model with lagged explanatory variables, e.g. last year's prices (exogenous) or even lagged cost shares (endogenous). Adding lagged variables reflects the idea that the impact of changes takes more than one time period to be fully realised. Such an extension of the model is associated with a loss of degrees of freedom. When estimating the original Translog, the equations are estimated one at a time. Opposite to this approach is a simultaneous estimation, where each cost share depends on the other cost shares in the same period. This too implies a considerable loss of degrees of freedom and more advanced estimation techniques. It should be clear, that a thorough sensitivity analysis would be very comprehensive and time consuming. A sensitivity analysis by the Generalised Leontief cost function may seem obvious. Briefly, the Generalised Leontief models a relation between quantities and the square roots of prices, and such an analysis would test the logarithmic relation of the Translog. Unfortunately, the application of the Generalised Leontief requires a conversion of data into a common measurement of the traded quantities for the dependent variables. Roundwood, sawnwood and panels are measured in cubic meters, while pulp and paper are measured in tonnes, and conversion into a common measurement like roundwood equivalents requires a critical assumption about conversion factors, viz. the conversion factor being equal across countries. This is not a problem for the Translog, because the cost shares are the dependent variables.

A different and straightforward approach would be to compare with the outcome of other studies, but as mentioned earlier, the literature provides limited room for such a comparison. Nevertheless, if a little conversion is allowed for, a few comparable expressions can be derived. The studies by Uusivuori & Kuuluvainen (2001) and Uusivuori & Kuuluvainen (2002) apply translog cost technology in the analysis of FAOSTAT data and estimate own and cross price elasticities. The commodity aggregates and separability structure differ from the present analysis, however. Vincent *et al.* (1991) apply a multi output profit function and data from different Japanese sources to estimate own and cross price elasticities. As will be explained later, expressions of substitution elasticities can be derived from own and cross price elasticities. Consequently, estimates of substitution elasticities will be produced from these studies in the cases where the aggregates do not differ much from those in the current paper. Comparison with the two first mentioned papers reflects the impacts of a slightly different data source, different aggregates and separability structure. Comparing with the last mentioned could be regarded as comparing functional forms, viz. cost minimisation vs. profit maximisation.

2.2.4 Model performance

Cost functions are assumed to be increasing and concave in prices, but this is not a 'built-in' property of the Translog, instead it relies on the estimation of the parameters. The assumption reflects the notion that consumers tend to buy less of a good if the price increases. If this condition is fulfilled the matrix of second order derivatives is negative semidefinite, which implies that the diagonal elements are non-positive. Negative own-price elasticities indicate that the assumption is fulfilled. Besides concavity, the application of an econometric cost function relies on a number of assumptions that are less evident than what have been mentioned so far, but none the less crucial to the evaluation of the estimates. The following is based on Jensen (2003), Otto (1998) and Greene (2003) and gives a brief overview of the underlying assumptions, how they are tested, implications and what can be done to improve the model performance. The Translog in (10) can be rewritten as

$$y = XB + \varepsilon \tag{11}$$

where y is a column vector of cost shares, X a matrix of explanatory variables – in this case prices, B a column vector of parameters and ε a column vector of model disturbance or residuals. It is common to consider X as the deterministic element and ε as the stochastic.

The residuals are assumed to have a zero mean value, to follow a normal distribution, to exhibit constant variance and to be independent of each other and the explanatory variables. The assumption of the residuals being independent of X is usually not a problem in static models such as the Translog applied here. It usually pertains to models with lagged endogenous variables. Nevertheless, the test is quite simple to perform; it is a question of regressing the residuals on the explanatory variables.

Constant variance has been termed homoscedasticity and the opposite heteroscedasticity. Heteroscedasticity may lead to unreliable variance estimates and therefore unreliable significance levels. Plotting the residuals against the observations of the different variables may tell if the residuals are heteroscedastic, but it cannot be taken as a certain proof. Instead a number of mathematical test have been developed, e.g. the Breusch-Pagan test, White's test and the Goldfeld-Quant test. Breusch-Pagan is sensitive to the residuals following a normal distribution, but contrary to the other two, it may identify the problematic variables. Therefore it will be applied here. Change of functional form or transformation of data may solve problems with heteroscedasticity.

The residuals are assumed to follow a normal distribution, even though it is not always a necessary condition for the regression itself, but convenient for constructing various other test statistics. Normality can be controlled for in different ways, e.g. via plots. On the other hand, browsing plots is quite time consuming when their numbers are high. The Shapiro-Wilk statistic indicates if the residual are a random sample from a normal distribution.

If the residuals are not independent of each other, but depends on the value of the preceding residuals, the model is misspecified in the sense that the model does not capture some effect of time. This phenomenon is known as (true) serial correlation or autocorrelation and may result in the estimates being inefficient and the level of significance unreliable. Autocorrelation may be due to time effects of both exogenous and endogenous variable and may consist of several time lags, e.g. the price of 1, 2, 3 or more years past, or past year's production or cost share. Many tests have been devised to check for autocorrelation, e.g. the Durbin-Watson test and the Breusch-Godfrey test. Durbin-Watson is frequently applied, but it suffers from some defects. Durbin-Watson may reveal autocorrelation of the first order only, e.g. last year's prices, but not higher orders. Furthermore Durbin-Watson does not capture the effect of missing lagged endogenous variables, only first order exogenous. As a result, the Breusch-Godfrey will be applied to check for autocorrelation up to the fifth order. There are many ways to deal with (true) autocorrelation, e.g. introducing lagged explanatory variable to the model or extending the residual to follow an autoregressive process of a given order. In all instances it will incur a trade-off with respect to degrees of freedom. It should be noted that in some cases inappropriate functional form may show as (false) autocorrelation. If this is the case the estimates may be biased and differ from the true value. True and false autocorrelation may be difficult to distinguish and therefore difficult to handle.

The matrix of explanatory variables or regressors (X) is assumed to have full rank, which means that there is no linear relation between the regressors, and the number of observations exceeds the number of variables. A violation of this is known as multicollinearity and it may cause unstable parameter estimates in the sense that they will be sensitive to even small changes in data. Moreover, the variance increases and therefore significance may be underestimated, even though the estimates are central. Multicollinearity indicates that one or more of the regressors may be redundant and should be excluded form the model. Time series analysis often suffers from problems with multicollinearity, because many variables tend to grow steadily over time. Multicollinearity can be addressed in a number of ways, e.g. by regressing differences instead of absolute values, but this will be at the expense of a loss of the information related to the absolute levels of the data. The most common test for multicollinearity is the calculation of the so-called condition index with zero as the best value and 30 as the critical limit.

The parameters, B, are assumed to be constant or stable across the observations, which is an especially important feature of a proper modelling of time series. If B is not stable, it could indicate a structural change that is not captured by the analysis. The tests for parameter stability applied here are the CUSUM and CUSUMQ tests. These tests assume that the recursive residuals, *e*,

(12) $$e_t = y_t - x_t \hat{\beta}_{t-1}.$$

exhibit a constant and standardised variance, W, of value 1 and a mean of zero if the *B* is stable. The basics of the tests are plotting the cumulated W against time to see if W stays inside its confidence bounds, usually the 95% limits. Sample plots are provided in section 3.3.1. Testing for a structural break is another approach to the question of parameter stability. The test is known as a CHOW test and it tests the hypothesis that the data set should be split into two (or more) parts, each with differing parameters, *B*. However, the CHOW test should be used with care, because it relies on a given time for the break point, and therefore the analyst can affect the outcome.

The model restrictions presented in (8) decrease the number of parameters to be estimated substantially. The restrictions bring about a gain of degrees of freedom, but they may also incur a loss of explanatory power, which is tested for by an approximate F-test. The F-test tells if the determinant of the variance matrix exhibits significant change as a result of the restrictions on the parameters.

2.3 The Elasticity of Substitution

2.3.1 Conceptual introduction

The elasticity of substitution is due to Hicks. The concept can be applied to any set of factor inputs, and production technology in a two-factor space is a convenient approach to this theory. Figure 2.1 depicts how different combinations of factor inputs, x_1 and x_2, produce the same level of output, $y = f(x_1, x_2)$. The technical rate of substitution (TRS) measures the *slope* of the isoquant, *y*, and tells us the required adjustment of x_2 that will keep output constant when x_1 changes. With constant output the TRS can be expressed as

(13) $$0 = \frac{\partial f}{\partial x_1} dx_1 + \frac{\partial f}{\partial x_2} dx_2$$

and be solved for

(14) $$\frac{dx_2}{dx_1} = -\frac{\partial f / \partial x_1}{\partial f / \partial x_2}.$$

The elasticity of substitution, σ, measures the *curvature* of the isoquant, and for a given output σ is computed as the percentage change in factor ratio input (x_2 / x_1) divided by the percentage change in the TRS

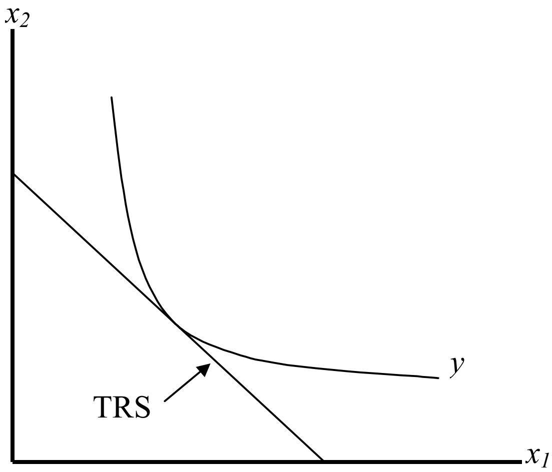

Figure 2.1 Production technology in two-factor space.

(15) $$\sigma = \frac{\Delta(x_2/x_1)}{x_2/x_1} \bigg/ \frac{\Delta TRS}{TRS}.$$

For small or marginal changes ($\Delta \rightarrow 0$) the elasticity of substitution can be expressed in logarithmic derivatives as in (16). In this case the denominator is often referred to as the marginal rate of technical substitution or MRTS

(16) $$\sigma = \frac{d\ln(x_2/x_1)}{d\ln|TRS|}.$$

The elasticity of substitution tells us how the ratio of factor inputs changes as the MTRS changes. In the cost minimising case the TRS equals the ratio of the input prices ($-p_1/p_2$), which may make the elasticity of substitution a little easier to comprehend. Consider a price increase of factor 1 ($\uparrow p_1$) in Figure 2.1; the slope of the TRS will increase and more of factor 2 will be used if the elasticity of substitution is positive. Two extreme cases are presented in Figure 2.2, a) perfect substitutes where any change to the MTRS will result in only one input factor being applied, and b) the factors are complements and no substitution takes place irrespective of the MTRS, e.g. busses and bus drivers.

Finally the Cobb-Douglas case should be mentioned. This is an iso- and unit-elastic case, where a 10% change in the MTRS yields a 10% change in ratio of factor input regardless of the TRS. In this case the curvature is hyperbolic and the isoquant will approach the abscissa and the ordinate but never intersect. The reader should note that unless we are in the one of the last three mentioned technologies, the

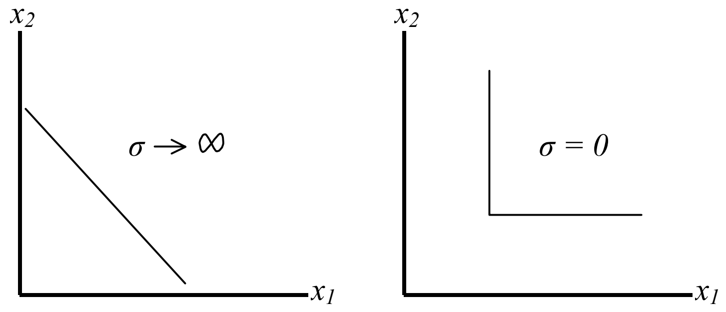

Figure 2.2 Extreme cases of the elasticity of substitution.

elasticity of substitution will differ for different TRS or positions on the isoquant Debertin (1986), Varian (1992).

2.3.2 How the elasticity changes

There is no evidence that the elasticity of substitution tends to be constant over time; it is more a question of a widespread practice to assume constancy, e.g. Greene (2003) "These elasticities will differ at every data point. It is common to compute them at some central point such as the means of the data." Suppose that the variation is systematic, e.g. it has an increasing trend, the associated constant means-of-the-data elasticity provides biased information. In the cost minimising case, it follows from Figure 2.1 and equation (16) that a change of the relative price incurs a movement along the isoquant and therefore a change of the substitution elasticity, unless we are in an iso-elastic case as outlined above. Computing the elasticity by each year's cost shares and plotting them against time may reveal changes. Unfortunately, this does not provide much reason for the change, if any. It follows from (16) that the elasticity may change in response to changes in the factor input ratio, the relative price or both, which should make it clear that it may not always be an easy task to separate the cause from the effect. However, in case the elasticity changes and the relative price remains constant, it can be concluded that the change is due to changes of preferences or technology (curvature).

2.3.3 Generalising the elasticity of substitution

Hicks was concerned with capital and labour substitution, and therefore his technology was designed to handle only two factors. Since then much effort has been given to generalise Hicks' notion into the case of more than two factors, which has led to quite different points of view. Frondel & Schmidt (2000) have expressed the problem as "… with more than two factors being flexible, the MRTS would not be determined uniquely." The following text is based on Blackbory & Russel (1989), Chambers (1994), Frondel & Schmidt (2000). It summarises the main solutions to the problem with the purpose of identifying an appropriate measure for this paper. Hopefully, the reader will realise that for a long way, it is a question of different measures answering different questions. Table 2.1 provides an overview of the different elasticities in differential form and parametric form in the Translog technology.

A straightforward suggestion is given by Chambers (1994), p33, who defines the *direct elasticity of substitution* (DES) by replacing the subscripts *1* and *2* in (15) by *i* and *j*. According to Chambers this measure can be interpreted as a short-run elasticity, because all other inputs are held fixed.

Probably the most widely used measure is the *Allen partial elasticity of substitution* (AES) proposed by R.G.D. Allen in 1938. It has been pointed out that the AES is not a measure of curvature; it is merely a *one-factor-one-price* elasticity of substitution (OOES), which expresses the effect of a price change in one factor to the factor input quantity of another. This gives the AES the characteristics of a cross-price elasticity, or at least, it should be interpreted as such.

The *Morishima elasticity of substitution* (MES) formulated by M. Morishima in 1967 can be considered a *two-factor-one-price* elasticity of substitution (TOES) and is in fact a measure of curvature. The MES expresses the effect of change in the price of one commodity to the input ratio of the same commodity and one other. The MES has the special feature of being asymmetric that is $MES_{ij} \neq MES_{ji}$, unless the production function is a member of the CES-Cobb-Douglas family. Asymmetry implies that the MES evaluates the substitutability with respect either the one or the other price. In line with this, one might ask how one price can be allowed to change without changing the relative price? Blackbory & Russel (1989) explain that when the number of factors exceeds two, any substitution elasticity is partial. For this reason, an equal percentage change of the one or the other factor input price incurs different changes to the optimal factor input ratio, and therefore the substitution elasticity is inherently asymmetric. In the recent literature there seems to be no doubt about the superior properties of the MES to the AES.

The *shadow elasticity of substitution* (SES) proposed by McFadden in 1968 is a *two-factor-two-price* elasticity of substitution (TTES). The SES is related to the MES by being a weighted average of the corresponding measures, MES_{ij} and MES_{ji}. The SES expresses how the input ratio of two commodities changes as the price ratio of the same commodities changes. Note from Table 2.1 that the SES is evaluated at constant costs. It is a symmetric measure of curvature and close to Hicks' notion.

It should be stressed that the DES, AES, MES and SES all assume constant output, which is the same as assuming that the level of output does not affect the elasticity of substitution (the curvature of the isoquant does not depend on the production level.) This assumption may not seem very realistic, but for the purpose of this analysis it is simply a necessary one, if things are not to be complicated further.

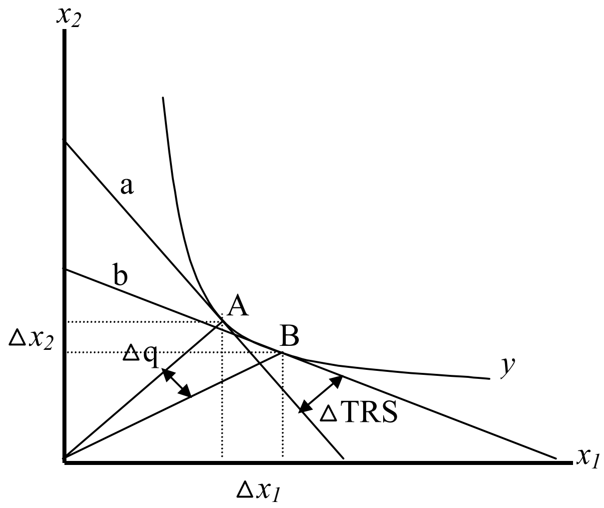

Figure 2.3 The elasticity of substitution.

Moreover, it is important to note that the substitution elasticities are based on own-price and cross-price elasticities that are derived from the dual approach. Therefore, the own-price and cross-price elasticities are so-called compensated elasticities, which means that the elasticities do not include effects of price changes to the overall level of consumption. For this reason, the DES, AES, MES and SES all measure pure substitution effects.

Figure 2.3 builds on Chambers (1994), fig. 1.11, p. 31, and extends Figure 2.1 to compare the AES and MES/SES (recall that the AES has the characteristics of a cross-price elasticity). The AES expresses Δx_1 as the response to a marginal change of the relative price (≡ΔTRS). The MES and the SES measure curvature as how the marginal factor input ratio (≡Δq) changes in response to marginal changes of the price relation (≡ΔTRS). This should make it clear that cross-price elasticities and the AES provide no information about the impact of the relative price change to the 'other factor', in this case Δx_2. The reader should realise that a change of relative prices in favour of x_1 does not necessarily incur a decline in the use of x_2. Such shifts in factor use depend on the substitutability of the two factors, which are captured by the MES and the SES, but not the AES and cross-price elasticities.

In the two-factor case, the different measures of substitution elasticity are identical and always positive. In case of more than two factors, the elasticity may turn negative. This has been termed *complementary behaviour* and it is a little tricky to interpret. In principle, the elasticity of substitution cannot be negative without associated output changes. Moreover, the measure assumes constant output in order to reflect a movement along the same isoquant, so there seems to be a problem with the interpretation of negative substitution elasticities. However, Chambers (1994), pp 33-34,

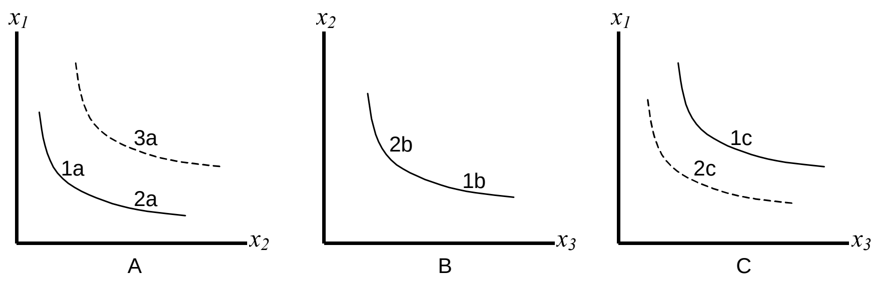

Figure 2.4 Substitution in the three-factor case.

provides a three factor example of the problems of generalising the two factor case to more factors, and this is helpful to understand the negative elasticities. Figure 2.4 reproduces Chambers' example and shows that a negative elasticity of substitution may come about by *moving* to another isoquant that represents the same output. In panel A and panel B the level of x_2 increases, resulting in less of x_1 and x_3 being used, and so the isoquant in panel C moves toward the origin, because less of x_1 and x_3 are required to produce the same output. The level of x_3 shifts the isoquant in panel A outward. The isoquants in panel A can be thought of as

(17) $$y = f(x_1, x_2 \mid \bar{x}_3)$$

where the position of y in the diagram depends of the different levels of x_3. Chambers seems to *define* the displacement of the isoquant and the movement from 1a to 3a via 2a as an expression of complementary behaviour. The literature does not provide other explanations to this, and it seems as if complementarity is the 'normal' interpretation, e.g. Greene (2003). The movement to another isoquant may be easier to comprehend if Figure 2.4 is considered in three dimensions. In three dimensions the isoquant becomes an isoquant *surface*, convex in all directions.

Table 2.1 Applied elasticities in differential and parametric form. Based on Blackbory & Russel (1981), Blackbory & Russel (1989), Chambers (1994), Frondel & Schmidt (2000), Frondel & Schmidt (2002)2)

Name	Differential form	Parametric form in the Translog cost function	Comments
Cost share, s_i, (of factor *i)*	$\dfrac{\partial \ln C(p,y)}{\partial \ln p_i}$	$\dfrac{p_i x_i}{C(p,y)}$	*C*(*p,y*) minimum cost of production for a given output, *y*.
Own price elasticity, η_{ii}	$(dx_i/dp_i)(p_i/x_i) = d\ln x_i/d\ln p_i$	$\dfrac{1}{s_i}(\delta_{ii} + s_i^2 - s_i)$	Measures the change in demand for input *i* when the price of input *i* changes.
Cross price elasticity, η_{ij}	$(dx_i/dp_j)(p_j/x_i) = d\ln x_i/d\ln p_j$	$\dfrac{\delta_{ij}}{s_i} + s_j$	Measure the change in demand for input *i* when the price of input *j* changes. (For all $i \neq j$)
Allen partial elasticity of substitution, AES_{ij}.	$\dfrac{\partial \ln x_i(p,y)}{\partial \ln p_j}$	$\dfrac{\eta_{ij}}{s_j} = \dfrac{\delta_{ij}}{s_i s_j} + 1$	OOES. Measures how the input of factor *i* responds to a change in the price of factor *j*.
Morishima's elasticity of substitution, *n*-input case, MES_{ij}.	$\dfrac{\partial \ln[x_i(p,y)/x_j(p,y)]}{\partial \ln p_j}$	$\eta_{ij} - \eta_{jj} = \dfrac{\delta_{ij}}{s_i} - \dfrac{\delta_{jj}}{s_j} + 1$	TOES. Measures how the *i,j* -factor ratio of input responds to a change in the price of factor *j*, for constant output. MES is asymmetric in many cases, $MES_{ij} \neq MES_{ji}$.
McFadden's Shadow elasticity of substitution, *n*-input case, SES_{ij}.	$\dfrac{\partial \ln x_i(p,y)}{\partial \ln(p_j/p_i)} - \dfrac{\partial \ln x_j(p,y)}{\partial \ln(p_j/p_i)}$	$\dfrac{s_i}{s_i + s_j} MES_{ij} + \dfrac{s_j}{s_i + s_j} MES_{ji}$	TTES. Measures how the *i,j* -factor ratio of input responds to a change in the *i,j*-factor ratio of prices, for constant output and cost.

The aim of this study is to provide a measure of how tropical and non-tropical wood products substitute. The study does not seek to reveal certain relations between specific commodities. This speaks in favour of some general measure of the elasticity of substitution, or in other words the measure should, as a point of departure, capture as many regards as possible. The Hicks notion of measuring the curvature of an isoquant has appealing characteristics because it is easy to comprehend and closely related to the well-known Slutsky decomposition of a price change effect into an income effect and a substitution effect. The DES assumes all other factors constant and therefore lacks general characteristics. With this in mind and with the special characteristics of the AES, the DES and the AES will not be dealt with further.

The asymmetry of the MES makes it particularly interesting because it allows for analysing a ratio of factor inputs from two different departures, viz. by changing one or the other price. It should be obvious that the MES may reveal information that differs from any of the other measures. Consider for example brown (cane) sugar and white (sugar beet) sugar. In Europe the prices may differ by as much as a factor three with cane sugar being the expensive one, and as a result the white sugar is by far dominating the market. Intuitively, due to differences in market shares or proportions, it can be expected that the price of white sugar affects substitutability much more than the price of brown sugar does. Such information can be captured by the MES, none of the symmetric measures poses this feature. On the other hand, the asymmetry doubles the amount of information to be considered, and therefore the MES will not be at the focus of the study. Still, the MES is an interesting measure and it will be presented to give an impression of how the MES varies compared to the SES.

Due to its generality and close resemblance of the Hicks notion the SES will be applied to express how the wood products substitute and in the analysis of variability over time. The reader should notice that the SES is a weighted average of the corresponding MES, which again is computed as the difference of the cross and own price elasticities. This implies that the magnitude of the measures tends to decrease as the complexity increases, and the SES might leave the impression that limited substitution takes place.

2.3.4 On the parametric approach

A few words should be said about the parametric approach to elasticities. In the Translog cost function the parameter estimates express a relation between *cost shares* and *prices*, and the estimates are tested against the hypothesis that the estimate equals zero. Rejection of the hypothesis is based on the significance, or probability, produced by a t-test and may lead to the acceptance of the alternative hypothesis that the estimate differs from zero. In this study parameter estimates are accepted if the probability is equal to or less than 5%. This is an arbitrary limit of course, and many econometric studies accept the 10% level. On the other hand, the probability of finding effects by chance increases with the number of explanatory variables, and therefore ‘large models’ as this one should not accept ‘low’ levels of significance.

In the computation of elasticities, the parameter estimates comprise one component and the cost shares the other component. In time series analysis it is common to apply the mean values of the cost shares in the data set, which will always be in the range 0 to 1. If the parameter estimate is insignificant it follows from the definition that it does not differ from zero, and therefore should be applied as a zero in the calculation of the elasticities. With this in mind please refer to Table 2.1 and see that the own-price elasticity becomes the cost share minus one and will be in the range –1 to 0, the cross-price elasticity becomes the cost share of ‘the other commodity’ and in the range 0 to 1, and the MES and SES tend to go to unity as the number of insignificant estimates increases. It may seem counter intuitive that a ‘zero’ relation between cost shares and prices brings about negative own price elasticities and substitution elasticities of unity. However, there are no contradictions to this. Think of the cost share as *price*quantity*. If a price change should leave the cost share unaffected, the quantity must change. This is what elasticities measure, viz. relations between *prices* and *quantities*. A similar rationale goes for the understanding of the cross-price elasticity. In case of the MES and the SES, insignificant parameters bring about unit elasticity of substitution, because the Translog reduces to the Cobb-Douglas technology. This reflects that the considered cost shares is unaffected by the price changes, because the price changes are fully offset via substitution in quantities.

The significance of the parameters has a special implication for how the elasticities develop over time. The parameters are assumed to be constant throughout the period, but the cost shares are allowed to vary, and it is this variation that makes the elasticities vary. However, it follows from Table 2.1 that if a parameter estimate is set to zero some of the cost share variation disappears from the calculation. It takes three parameters and two cost shares to compute a SES, and therefore, if all three parameters are zero, the SES not only becomes unity, but also constant throughout the period. Due to this special feature of the technology, the analysis of how elasticities develop over time may prove sensitive to the significance of the parameters.

Finally, the reader might like to know if the elasticities are significant in the sense that they differ from zero. Unfortunately, this is not an easy task, because the distribution of the elasticities is not known. As a consequence, the elasticities must be judged upon their standard deviations or standard errors. The parameters and the cost shares contribute to the standard deviation of the elasticities, but it seems common to consider the cost shares as non-stochastic and only apply the deviation from the parameters Otto (1998). This is probably due to simplicity, because the inclusion of the cost share variance and parameter-cost-share covariance produces more complex expressions. Cost share variance will also be disregarded here, but the reader should note that it implies a systematic underestimation of the standard deviations of the elasticities.

2.4 Data

2.4.1 Data sources

Two data sources are drawn upon in this study; production figures were downloaded from the FAOSTAT[1] database and the trade figures were downloaded from EFI-WFSE Trade Flow Database[2]. FAOSTAT provides trade statistics as well as production figures, while EFI-WFSE provides trade statistics only. The reason for drawing upon both, and not FAOSTAT only, is due to consistency problems with the latter part. Initially FAOSTAT collected production and trade statistics directly from member countries by manually entering data from questionnaires and national statistical yearbooks into the FAOSTAT data collection. Hereafter data were manually handed over to the United Nations Statistical Division (UNSTAT). Since the mid 1980's the exchange of data was fully electronical. It has been recognised that the data collection suffers from inconsistency in the form of inaccuracies due to miss-interpretation of data and problems with handling missing data. The European Forest Institute Michie & Wardle (2002) developed the EFI-WFSE Trade Flow Database, which takes UNSTAT data and deals with the consistency problems of the FAOSTAT trade statistics. For this reason, the EFI-WFSE data are believed to provide an improved basis for trade analysis compared to the FAOSTAT trade data. However, since production figures are required too, FAOSTAT production data are applied as well. It follows, that the EFI-WFSE data are manipulated FAOSTAT data, and the outcome of the analysis may therefore be sensitive to the choice of data source. On the other hand, it is probably an insurmountable task to clarify the full implications hereof, and therefore the study assumes that the application of the EFI-WFSE is the best choice between the two sources. Figure C.1 in Appendix C compares a selection of EFI-WFSE and FAOSTAT data.

The data set covers a span of 40 years, 1962 – 2001, and figures for six consumer countries: France, Germany, Italy, Japan, the United Kingdom and the United States. German data from 1962 to 1990 (prior to the re-unification) is a merger of data for the former German Democratic Republic and the Federal Republic of Germany. The criteria for selecting countries reflect a mix of the purpose of the study and the limitations due to the data availability. The study attempts to capture the variability in substitution patterns among the major tropical wood consuming regions. This implies that the countries must

[1] FAOSTAT: Statistical office of the Food and Agricultural Organisation of the United Nations.
[2] EFI-WFSE: Co-oporation between the European Forest Institute and the World Forest, Society and Environment.

Table 2.2 Specification of commodity aggregates. Source: FAO (1994)d

Commodity aggregate	Specification
Roundwood	Wood in the rough, with or without bark, round, split, roughly shaped, roughly squared or pointed, impregnated. All wood from removals, including sawlogs, veneer logs, pulpwood, and other industrial roundwood including chips and particles, fuelwood.
Sawnwood	Sawnwood, unplaned, planed, grooved, tongued, etc., lengthwise sawn or profile chipped, with or without joints. In most cases more than 5mm in thickness.
Wood Based Panels	Veneer sheets, plywood, particleboard, compressed and non-compressed fibreboard. Thin sheets of wood for plywood, laminated constructions, furniture, etc.
Wood Pulp	Mechanical, semi-chemical, chemical and dissolving wood pulp.
Paper and Paperboard	Newsprint, printing and writing paper, other paper and paperboard, e.g. Kraft papers.

exhibit imports of tropical and non-tropical wood based products within all of the aggregates and throughout the whole period. If this is not fulfilled the model will lack price expressions. For that reason, the study does not provide a strictly representative picture of world consumption and substitution; clearly, data are biased towards the consumption in the northern hemisphere and developed countries. With five commodity aggregates, six countries and 40 years data, the raw data set comprise a total of 1,200 observations.

The structure of the FAOSTAT database does not allow for including China in this analysis, which is quite unfortunate because China became the world's largest importer of tropical roundwood during the late 1990s Johnson *et al.* (2003). FAOSTAT does not distinguish between China and Taiwan; production and trade figures of Taiwan are included in the figures for China. This analysis regards Taiwan as a tropical exporting country, for reasons that will be given below. Therefore, should China be included, it would require data from a third data source about the Taiwanese domestic production to supplement the FAOSTAT figures and compute the Chinese apparent consumption.

2.4.2 Separability structure

Raw data cover the five major commodity aggregates; *Roundwood*, *Sawnwood*, *Wood Based Panels*, *Wood Pulp* and *Paper and Paper-*

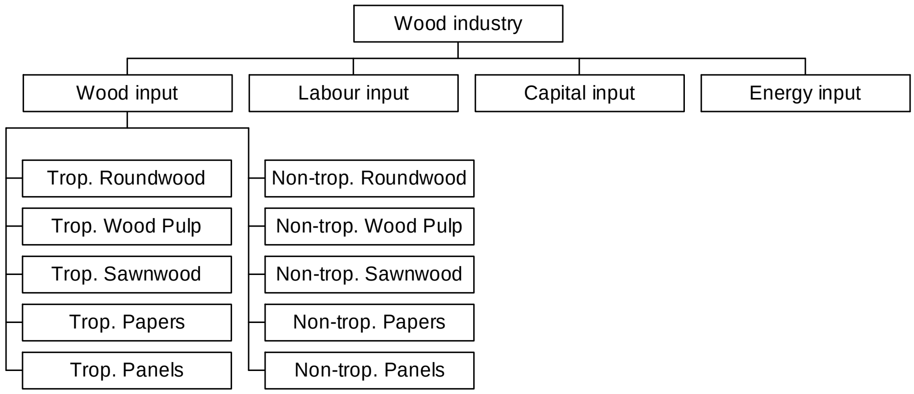

Figure 2.5 The separability structure of the analysis.

board. These are the major groupings in the SITC[3] for forest products and each comprises a range of sub groupings and commodities, which are presented in Table 2.2. To eliminate any doubt; for each of the five aggregates, the study distinguishes between tropical and non-tropical origin, with tropical origin defined as origin in one of the 60 below mentioned countries and non-tropical as the rest. Therefore the system of equations in (10) comprise 10 equations, each with 10 prices as explanatory variables. Furthermore it is important to note that the distinction concerns overall consumption of tropical and non-tropical wood products, which should not be confused with imports only. Figure 2.5 presents the separability structure of the model. The figure shows that all 10 aggregates are considered as possible substitutes for each other. It should be noted that the tropical forests are predominantly hardwood forests and the non-tropical forests are softwood forests to a wide extent. Hardwoods and softwoods differ with respect to the length of the wood fibres and therefore exhibit different technical properties. In general, softwood fibres are longer than hardwood fibres, and consequently the distinction between tropical and non-tropical origin reflects a distinction between short and long wood fibre properties.

2.4.3 Tropical countries

Tropical countries are regarded as countries with landmass between the tropics of Capricorn and Cancer. The definition covers more than 100 countries of which many are irrelevant because they do not have forests or export forest products themselves. Barbier *et al.* (1994) apply the definition *countries with the majority of their landmass lying between the tropics* and include 55 countries. Two countries more or less outside the tropics are considered because of their vast exports of processed tropical wood, viz. Taiwan and South Korea Kumar (1982).

[3] Standard International Trade Classification (Rev. 3 UN 1985), which is consistent with the Customs Co-operation Council trade classification - the harmonised system (HS).

Table 2.3 Tropical countries.

Tropical Africa	Tropical Central and South America	Tropical Asia
Cameroon	Belize	Brunei Darussalam
Central African Republic	Bolivia	Cambodia
Congo	Brazil	Fiji
Côte d'Ivoire	Colombia	Hong Kong
Dem. Rep. of the Congo	Costa Rica	India
Equatorial Guinea	Cuba	Indonesia
Gabon	Ecuador	Laos
Ghana	El Salvador	Malaysia
Guinea	French Guinea	Myanmar
Guinea-Bissau	Guatemala	Papua New Guinea
Kenya	Guyana	Philippines
Liberia	Honduras	Singapore
Madagascar	Mexico	Solomon Islands
Malawi	Nicaragua	South Korea
Mozambique	Panama	Sri Lanka
Nigeria	Paraguay	Taiwan
Sierra Leone	Peru	Thailand
Tanzania	Suriname	Vanuatu
Zimbabwe	Togo	Vietnam
	Trinidad and Tobago	Yemen
	Venezuela	

In 2002 the number of ITTO producer member countries was 32 of which only Togo and Venezuela were not included in the above ITTO (2004). Togo and Venezuela will be included along with Vietnam, which has become a relatively large exporter of logs and sawnwood recently. In sum, the definition of tropical countries applied here comprises 60 countries, which are listed in Table 2.3. The inclusion of countries like Taiwan, South Korea and Singapore may lead to an overestimate of the tropical exports, because parts of the processing are based on non-tropical logs which cannot easily be adjusted for. On the other hand, Chinese exports are excluded, even though a large share of the Chinese forest area is located in the tropics. This is due to the difficulties of segregating the tropical part of the Chinese export from the non-tropical part. Furthermore, a range of tropical countries like Benin, Burkina Faso, Chad, Eritrea, Senegal, Sudan and Uganda are excluded from the study. These are all countries with quite small exports of forest products. The exclusion of China and the minor exporters leads to a systematic underestimate. As a result, it is assumed that the 60 countries named in Table 2.3 comprise a fair measure of the tropical exports. Furthermore, the relatively large number of countries may catch up on situations where the importing countries switch between the different sources of tropical origin.

2.4.4 Data manipulation

For each country, apparent consumption of non-tropical products is computed as domestic production minus exports plus imports of non-tropical origin. Consumption of tropical products is represented by the *import* of tropical products, with the implicit assumption that the tropical products are fully consumed and not re-exported. Changes in domestic stocks are not captured by the measure of apparent consumption, application of a moving average probably would. On the other hand, a moving average may result in a loss of information, because data is ‘smoothened’ and furthermore, the choice of time span is arbitrarily set, which leaves room for the analyst to affect the outcome.

For each year and each commodity aggregate, the unit prices are computed as the import values divided by the import quantities. These prices are current prices, due to the import values being measured in current terms. Since the importing countries are assumed to react on real prices, a conversion is done by a price index. A number of price indexes have been developed, e.g. the Laspeyres and Paasche price indexes are very common. The Laspeyres price index is defined as

$$\frac{\sum P_t Q_0}{\sum P_0 Q_0}(100) \tag{18}$$

and the Paasche price index is defined as

$$\frac{\sum P_t Q_t}{\sum P_0 Q_t}(100). \tag{19}$$

For both indexes P_t denotes observed price in year t, Q_t the observed quantity in year t and P_0 and Q_0 price and quantity in the base year. The Laspeyres index is known to overestimate the development in prices and the Paasche index is known to do the opposite. The reason is that none of the indexes take into account that the consumers may react to a price change by substituting for other goods. Fisher’s ideal index compensates for this defect

$$\sqrt{(\text{Laspeyres index})(\text{Paasche index})}. \tag{20}$$

Fisher’s ideal index is the geometric mean of the other two, which is an appropriate way of averaging factors or ratios Wonnacott & Wonnacott (1990).

2.4.5 Further on prices

The prices are import prices registered at the national borders. For this reason prices are exclusive of taxes, customs tariffs and profits in the importing country, but include export taxes, transport and insurance costs. Export prices are not given any role in the analysis. Export prices are not included as explanatory variables, nor are they part of the calculation of the apparent consumption, which is the basis for the cost shares in (10). Furthermore, it is assumed that the prices of domestic manufacture equal the prices of the non-tropical imported goods net of taxes and tariffs. This may seem as a fairly crude assumption, but it is a necessary one, because the prices of domestic manufacture are very difficult to access contrary to import prices, which are registered when crossing the borders. It will be very complicated to accommodate for the effects of tariffs, because the tariffs vary across the commodities, over time and across countries. Furthermore, each importing country applies different tariff rates for different countries of origin. For the moment the relevant tariff rates range from 0 to 10 percent for roundwood, sawnwood and panels. These rates were reduced by as much as a third in the mid 1990s as an outcome of the Uruguay Round. On January 1st, 2004, the tariffs on the EU imports of pulp and paper were fully removed Barbier (1996), ITTO (1997). So, besides pulp and paper, the tariffs tend to increase with the level of value added, which is known as tariff escalation and implies that the so-called effective rate of protection exceeds the nominal tariff. Therefore nominal tariff rates tend to underestimate the real impact in terms of protection level Kjeldsen-Kragh (2001).

2.4.6 Missing and extreme observations

There are no missing observations in the raw data set, but cells with a zero for production, traded quantity and traded value occur. When the traded quantity and/or the traded value is/are zero prices cannot be computed. Missing prices are not accepted by the structure of the Translog and require replacement by realistic price estimate or 'synthetic prices'. When the traded quantities are very small the price estimates tend to fluctuate because of round-off errors. Especially tropical wood pulp and paper products are affected by this problem in the first third of the time period, because trade in these products is close to non-existent. To catch up on the data weaknesses, the data set was browsed for missing and extreme prices. Extreme prices are defined as prices that are more than double or less than half the value of the previous year. Each missing or extreme price was replaced by a synthetic estimate based on a reference country. The synthetic price estimates are computed by transferring a relative price change from the reference country to the preceding or following year of the problematic cell. The idea is to maintain level differences between the countries but to assume that the price changes follow similar patterns. By this approach 20 missing prices and 10 extreme prices were replaced, which account for 0.25 percent of all price estimates. The details are presented in Appendix D. From the appendix a few interesting details can be seen. Tropical Wood Pulp seems to be the most problematic commodity and accounts for more than two thirds of the price problems. Furthermore, it is evident that the price problems pertain to the first half of the data set.

2.4.7 Applied data in brief

The following text briefly presents the major trends in the applied data. A complete graphical presentation of the data is given in Appendix A.

Figure A.1 to A.24 graphs the apparent consumption of tropical and non-tropical products. For France, Germany, Italy and Japan the consumption of tropical roundwood declines steadily throughout the period, while the United Kingdom and the United States exhibit more or less constant consumption. Across the countries, tropical sawnwood consumption shows mixed patterns with respect to development over time and relative magnitude compared to tropical roundwood. For all countries the consumption of tropical panels increases throughout the period. Until the late 1970s consumption of tropical wood pulp and tropical paper is close to non-existent, hereafter the consumption of tropical pulp grows rapidly from across the countries. With a delay of approx. five years, the consumption of tropical papers commence a steady growth too, but at a lower rate than tropical pulp. For the non-tropical products, all countries besides Japan exhibit steady growth in overall consumption of roundwood, sawnwood and panels. Germany seems to have suffered from a storm in the late 1980s, and again in 2000 a storm seems to affect roundwood production in France and Germany. Across all countries the consumption of non-tropical pulp grows slowly, but steadily throughout the period. Consumption of non-tropical paper is remarkable, it doubles from 1962 to 2001 in the cases of the United Kingdom and the United States, France, Germany and Italy triple, and in the case of Japan, consumption increases as much as eight times.

The figures A.25 to A.84 graph current and real prices of each commodity aggregate for each country. The amount of price information is substantial and cannot be given in full here. Therefore the following will try to capture only the main trends with respect to price developments and level issues in terms of real prices.

For France, Germany and Italy, tropical roundwood prices are relatively stable around 200-300 US$/CUM until 1999, hereafter the prices lose approx. 50% in one year and do not seem to recover. This marked price reduction is somewhat bigger than the one noted by the ITTO (2004), which is around 30%. For Japan the price fluctuates in the range 100-200 US$/CUM with a declining trend after 1991. For the United Kingdom the price is stable around 300 US$/CUM until 1980, hereafter the price declines to less than 100 US$/CUM at 2001. Tropical roundwood prices for the United States decline from 150 US$/CUM to approx. 40 US$/CUM throughout the period.

Compared to tropical origin, the non-tropical roundwood prices are more homogeneous across countries and in the range 60-150 US$/CUM. The prices decline steadily throughout the period, except for the United States, which shows an opposing trend.

Tropical sawnwood prices are in the range 300-800 US$/CUM and show an increasing trend. In the case of the US the price level is approx. 100 US$ lower and with a somewhat stronger increasing trend. Non-tropical sawnwood prices are stable in the range 200-300US$ and seem to peak in the middle of the 1990s. Again the US exhibits an anti-trend with a price decline from 200 to approx. 120 USD.

The prices of tropical panels are down from more than 1000 US$/CUM to around 600 US$ over the 40 years. Non-tropical panels fluctuate around 500US$, and it can therefore be said that the tropical and non-tropical prices are approaching the same level.

Wood pulp prices fluctuate around 700 US$/MT across countries and origins, although the level is around 150 US$ lower for Japan and the United States. For tropical origin, the fluctuations are quite high in the first half of the period. In the second half the prices of both origins are volatile and changes by as much as 20% from year to year. Such changes are confirmed by Bolton (1998).

Tropical paper prices fluctuate heavily until 1980. Hereafter the prices are stable around 1000 US$/MT for the European countries and some 300 US$ less for Japan and the US. Non-tropical papers are remarkable stable across all countries. The price level is close to 1000 US$ at the European borders, 800 US$ in Japan and a little less than 700 US$ for the United States.

Cost shares are graphed in Figure A.85 to A.96. The reader will immediately realise that the overall value of the tropical products constitutes a very limited share of overall costs. For all countries the shares are in the range 1,5% - 6% in 2001, with a maximum of 10% for Japan in the late 1970's. The United States exhibits increasing shares of tropical origin, while the other five countries exhibit decreasing shares, so there seems to be opposing trends with respect to overall consumption of tropical products. One common trend can be identified: Across all countries the consumption of tropical wood pulp and paper products tends to increase steadily from a close-to-zero-level in 1980 to as much as half of the tropical imports in 2001. Furthermore, with the exception of the United Kingdom and the United States, the cost shares of tropical roundwood tend to level off around 1970 and decline hereafter. The marked decline in the cost share of tropical roundwood and the end of the period is related to a steep price decline. Even though all countries face such a decline in the price of tropical roundwood, the French cost share seems much more responsive than the ones of the other countries.

As mentioned above, non-tropical products account for the major part of the overall consumption, and the cost shares of pulp and paper are dominating and increase steadily from 40% in 1962 to 60% in 2001. The increase of pulp and paper seems to be at the expense of a decline in the cost share of non-tropical roundwood. These patterns are similar for all of the countries, in the sense that each commodity follows the same trends, but the cost shares vary with respect to relative and absolute magnitudes.

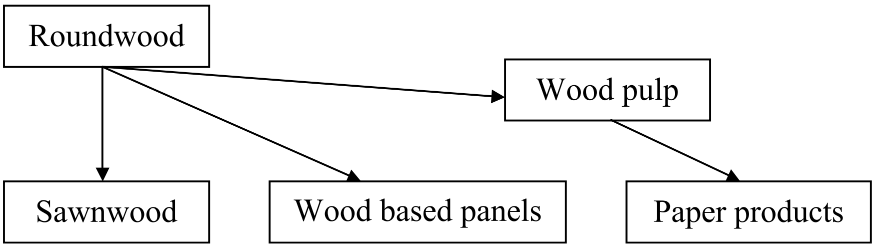

Figure 2.6 The conversion of roundwood.

2.5 Application of substitution elasticities

2.5.1 Delimitations

Recall from equation (10) that the Translog cost function comprises a demand system of ten equations, each with ten explanatory price variables. This system produces (((10*10)-10)/2)=45 symmetric substitution elasticities for each of the six countries, which is a fairly high number to interpret and present. However, it can be argued that some of the elasticities are more meaningful than others. Figure 2.6 outlines the inter-linkages and the level of processing between the wood products aggregates of the analysis. Roundwood is the basic raw material for the production of sawnwood, panels and pulp, and pulp is the basic raw material for the production of paper. The level of processing is synonymous with the level of value added, and therefore the value of the products increase along with a movement from the upper left corner and down and right in the figure. This result was verified in the preceding section. Within each of the five aggregates one substitution elasticity between tropical and non-tropical origin is estimated. Between roundwood and sawnwood, panels and pulp, elasticities are estimated within and between origins, which produces another twelve. Finally, another four elasticities are computed within and between origins of pulp and paper. In sum, instead of 45, 21 substitution elasticities are estimated, of which five are within-aggregates and 16 are between-aggregates. The remaining 24 elasticities reflect substitution in cases that are less straightforward to interpret, e.g. between tropical sawnwood for non-tropical paper, and for this reason these are not presented.

2.5.2 Applications

The following example presents the application of the elasticity of substitution in relation to trade regulation. Figure 2.7 resembles Appleyard & Field (1998), Figure 4, p. 92, which shows how an open economy gains from trade. The PPF denotes the physical production frontier, which represents the possible combinations of the production of good X_1 and X_2, in this case let it be pulp and paper respectively. In the initial situation the imports of paper are subjected to a tariff, T,

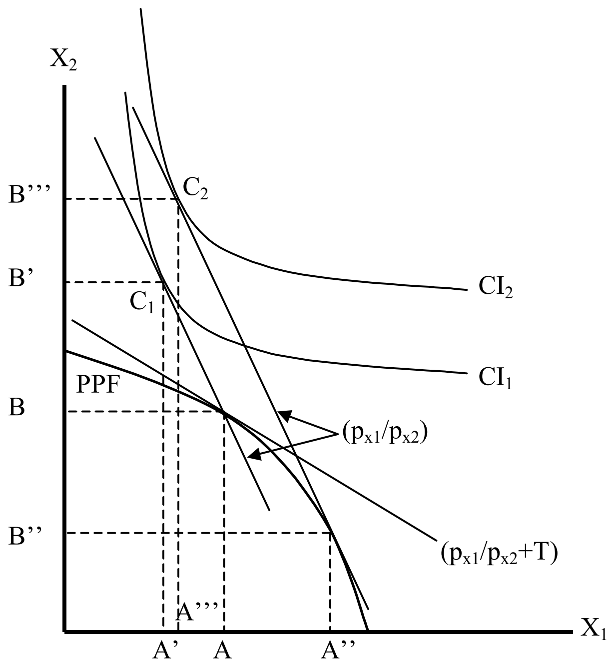

Figure 2.7 Trade and the impact of trade regulation.

which produces the relative price (p_{x1}/p_{x2}+T) faced by domestic industry. Production is at (A, B), consumption is (A', B') denoted by C_1 on the indifference curve CI_1, pulp export is AA' and paper import is BB'. Now suppose that the tariff is abolished and the domestic industry faces a new set of relative prices, viz. the 'world market price' (p_{x1}/p_x). Due to the change in relative prices, the domestic industry changes its production composition to (A'', B'') because the domestic country has a competitive advantage in pulp (X_1) and a competitive disadvantage in paper (X_2). Hence, consumption moves to C_2 on the higher indifference curve CI_2 and export of X_1 increases to A'''A'' and imports of X_2 increases to B'''B''. In sum, overall consumption increases and the production composition changes due to the abolishing of the tariff. This phenomenon is termed *trade creation*, and it reflects how welfare is gained by improved exploitation of comparative advantages. If we reverse the scenario and impose a tariff, production is distributed towards less efficient production patterns and therefore welfare is forgone. This has been termed *trade diversion*.

The elasticity of substitution plays a dual role in Figure 2.7. The curvature of the PPF reflects how the domestic industry may switch or substitute the production of one good for another. In case of a low substitutability the PPF become closer to a right angle and the impact of trade regulation to the production composition is limited. In the opposite case, the PPF is more flat and the production composition more sensitive to trade regulation. Moreover, the elasticity of substitution is reflected in the curvature of the indifference curves and therefore decisive to the consumption composition. The usefulness of the elasticity of substitution is made clear in Figure 2.7 and when the analysis considers tropical value added goods the implications are particularly interesting. Such analysis may tell us about the possibilities of moving the production down stream, which developing countries face.

3 Results

This chapter presents the results of the regressions and computation of substitution elasticities. The first part addresses the initial regressions and how a few, but major problems, had to be overcome before the analysis could proceed to the elasticities. Furthermore, the issue of the model performance is considered in the first part. The second part presents the parameter estimates. The third part deals with the elasticity of substitution, it provides an overview of the main trends and finally it encompasses how the elasticities develop over time. The fourth part compares the results with other studies, and the fifth part addresses the reasons for changes to the elasticities.

The SAS ETS software, which is a part of the SAS system and a dedicated package for econometrics, was the primary toolbox for the statistical analysis. The ETS software comprises a range of statistical procedures, of which the procedures MODEL, AUTOREG and REG were frequently applied. The graphs are produced by the GPLOT procedure, which does not give beautiful presentations of data, but it is quite efficient for producing many graphs. Examples of the SAS syntax are presented in Appendix D and examples of the SAS output are presented in Appendix E.

3.1 Model performance

3.1.1 Initial regressions

The first regressions comprised the 1962-2001 data set, absolute figures and an attempt to catch up effects of technological change by including time as an explanatory variable. From the very beginning, the Translog suffered from severe problems with accepting the restrictions on the parameters, cf. equation (8). Multicollinearity and autocorrelation seemed to be the reason. The condition index was 5-digit and therefore unacceptable (recall from 2.2.4 that the critical range is 30-100.) The problem was reduced to a '4-digit problem' in response to the exclusion of time. The solution seemed to be regressions on differentials of cost shares and prices, which reduced the condition index to the range 20-30. Hereafter, time was reintroduced, which caused the condition index to jump to a 3-digit level. So it was concluded that technological change could not be incorporated into the model by a time variable. However, solving the problem with multicollinearity did not lead to the acceptance of the homogeneous or the symmetric Translog.

The autocorrelation problem appeared quite pervasive and in fact it was never solved. Autocorrelation seemed to be a consequence of imposing the symmetry restriction, which reduces the number of parameters from 99 to 63. In many cases, the Breusch-Godfrey test statistics for the tropical roundwood equation were significant at the 0,01% level for the 1^{st} to the 5^{th} order, and therefore the problem could not be ignored. Even though the symmetry restriction is quite a strong one, it is not necessarily a source of autocorrelation; it could be due to many other factors. Therefore a wide range of possible solutions were explored, which are outlined in the following:

- Three-year moving averages of absolute values and differentials were applied. Moving averages may reduce the disturbance by smoothing data and catching up effects of changes in stocks.
- Extension of the model by an AR(1) process. Higher orders were not explored because of convergence problems for the ITSUR. An AR(n) process allows the stochastic error term to depend upon previous periods up to the n^{th} order.
- Inclusion of 1^{st} order lagged explanatory variables – exogenous as well as endogenous. Such variables model the assumption that the dependent variables react to changes in a previous period.
- Inclusion of a price index for crude oil to question the separability structure with respect to energy. The energy question was chosen because the manufacture of pulp and paper requires vast amounts of energy.

However, the autocorrelation situation did not improve, and therefore the homogenous Translog model was explored for a structural shift and for parameter stability by the CHOW test and the CUSUM and CUSUMSQ tests, respectively[4]. The CUSUM and CUSUMSQ tests revealed severe problems with the equations for tropical wood pulp and tropical papers. The corresponding prices tend to fluctuate heavily in the first third of the data set, which is most likely caused by the very small or missing figures. This notion is supported by the outcome of handling the missing and obscure price estimates, which mostly concerns the tropical pulp and papers (cf. Appendix D). Therefore, the quantities and amounts of the tropical pulp and paper were aggregated across countries for the first 15 years of the data set, and common price expressions were computed and added to each countries data set. The idea was that by aggregating data the problem of the price estimates being based on small figures might be solved. Unfortunately, this did not bring about any improvements.

The CHOW tests indicated a structural shift for tropical roundwood, non-tropical roundwood and non-tropical wood pulp between 1976 and 1977. Unfortunately, the SAS package does not allow for the estimation of a system of equations, which includes a structural shift. For this reason, the first 15 years of the data set was excluded from the analysis, which reduced the autocorrelation to a much more acceptable level and made the parameter restrictions fully

[4] SAS cannot perform the CHOW test on a system of equations; furthermore the MODEL procedure cannot perform the CUSUM/CUSUMSQ tests, unless extensive programming is done. The AUTOREG procedure can easily do the tests, but only one equation at a time; therefore the symmetric model was not tested. Instead, each equation was tested individually with homogeneity imposed.

acceptable. So the autocorrelation problem was never solved, instead it was partly avoided by omitting the first 15 observations. Table 3.1 and Table 3.2 display the autocorrelation for the two data sets, and show that the problems are far from evenly distributed over countries or equations.

Table 3.1 Results of the Breusch-Godfrey tests of autocorrelation up to the 5th order for the 1962-2001 data set. *=5% level, **=1% level, ***=0,1% level, <0,0001=0,01% level.

	Order	France	Germany	Italy	Japan	UK	US
	1	<0.0001	<0.0001	<0.0001	***	<0.0001	NS
	2	<0.0001	<0.0001	***	**	***	NS
TRW	3	<0.0001	<0.0001	***	***	***	NS
	4	<0.0001	<0.0001	**	**	***	NS
	5	<0.0001	<0.0001	**	**	**	NS
	1	<0.0001	<0.0001	**	<0.0001	**	***
	2	<0.0001	<0.0001	**	***	**	**
NTRW	3	<0.0001	<0.0001	**	**	**	**
	4	***	<0.0001	*	**	*	**
	5	<0.0001	<0.0001	*	**	*	**
	1	*	<0.0001	**	**	<0.0001	**
	2	*	<0.0001	**	*	<0.0001	*
TSW	3	**	<0.0001	**	*	<0.0001	*
	4	*	<0.0001	*	NS	<0.0001	*
	5	*	<0.0001	*	*	***	*
	1	**	<0.0001	***	*	**	**
	2	*	<0.0001	**	NS	**	**
NTSW	3	NS	<0.0001	**	*	*	**
	4	*	<0.0001	**	NS	*	**
	5	NS	<0.0001	**	**	**	*
	1	**	<0.0001	*	*	<0.0001	**
	2	*	<0.0001	NS	*	<0.0001	**
TWP	3	*	<0.0001	NS	*	***	**
	4	*	<0.0001	*	NS	***	*
	5	*	<0.0001	*	*	**	*
	1	*	<0.0001	**	<0.0001	<0.0001	**
	2	*	<0.0001	**	***	<0.0001	*
NTWP	3	NS	<0.0001	*	***	<0.0001	**
	4	*	<0.0001	*	***	<0.0001	*
	5	*	<0.0001	*	***	<0.0001	**
	1	***	<0.0001	***	*	**	**
	2	**	<0.0001	*	*	**	**
TPU	3	**	<0.0001	*	*	*	**
	4	**	<0.0001	NS	*	*	**
	5	**	<0.0001	NS	*	*	*
	1	***	<0.0001	**	**	***	**
	2	***	<0.0001	*	***	**	*
NTPU	3	***	***	**	**	**	**
	4	***	***	**	**	**	*
	5	**	***	**	**	*	*
	1	**	<0.0001	***	NS	**	**
	2	**	<0.0001	**	NS	***	**
TPP	3	**	<0.0001	**	NS	**	*
	4	**	<0.0001	**	NS	***	*
	5	**	<0.0001	**	NS	***	NS

Table 3.2 Results of the Breusch-Godfrey tests of autocorrelation up to the 5th order for the 1977-2001 data set. *=5% level, **=1% level, ***=0,1% level, <0,0001=0,01% level.

	Order	France	Germany	Italy	Japan	UK	US
	1	**	*	**	<0.0001	***	**
	2	**	*	**	***	***	**
TRW	3	**	NS	*	***	***	**
	4	**	NS	*	***	**	*
	5	**	NS	NS	**	**	*
	1	**	**	<0.0001	***	**	**
	2	**	**	***	<0.0001	*	**
NTRW	3	**	**	***	***	*	**
	4	**	**	**	***	*	**
	5	*	**	**	**	*	**
	1	*	**	***	<0.0001	**	*
	2	*	**	***	***	**	*
TSW	3	*	**	***	***	**	*
	4	*	**	***	***	*	*
	5	NS	**	**	***	*	NS
	1	**	**	***	**	***	***
	2	*	**	**	**	**	***
NTSW	3	*	**	**	**	**	**
	4	*	*	**	*	**	**
	5	*	*	**	*	**	*
	1	**	**	*	**	**	***
	2	*	*	NS	**	**	***
TWP	3	*	*	NS	**	**	**
	4	*	NS	NS	**	**	**
	5	NS	NS	NS	*	**	**
	1	*	**	**	<0.0001	**	***
	2	NS	**	*	<0.0001	**	***
NTWP	3	NS	**	*	***	*	**
	4	NS	**	**	***	*	**
	5	*	*	**	**	*	**
	1	**	***	***	***	**	***
	2	*	***	***	***	*	***
TPU	3	**	**	***	***	*	**
	4	**	**	***	**	NS	**
	5	**	**	***	**	NS	**
	1	**	**	***	*	**	<0.0001
	2	**	*	***	*	**	***
NTPU	3	**	*	***	*	**	***
	4	**	**	**	*	*	***
	5	**	**	**	*	*	**
	1	**	**	***	*	**	<0.0001
	2	**	**	***	*	**	***
TPP	3	*	**	***	*	**	**
	4	*	**	**	*	**	**
	5	*	*	**	NS	**	**

Table 3.3 Outcome of the CHOW test that assumes a structural shift in 1976-1977. *=5% level, **=1% level, ***=0,1% level.

	France	Germany	Italy	Japan	UK	US
TRW		**		**	***	
NTRW	*		*	*		
TSW						
NTSW			**			*
TWP						***
NTWP				**		**
TPU						
NTPU			***		**	**
TPP						

Table 3.3 provides an overview of the CHOW tests, which indicate a structural shift in 1976-1977. Table 3.4 presents the CUSUM/CUSUMSQ analysis of the two data sets. By omitting the first 15 observations (38% of the dataset) the number of observations outside the 95% confidence bounds was reduced from 134 to 25 (by 81%). The bottom part of the table presents the observations outside the bounds in the 1977-2001 data set, which indicates another structural shift in the middle-late 1990s. Such structural shift will not be encountered here, because less than half the equations seems to require it, and moreover, the number of observations compared to the number parameters to be estimated in each period will be quite critical in both periods. Figure 3.1 displays sample plots of the CUSUM and CUSUMSQ tests of non-tropical panels for France and shows how the tests differ. Finally, Table 3.5 presents the approximate F-tests of imposing the homogenous and symmetric restriction on the Translog. The table shows that the restrictions are fully acceptable in the 1977-2001 data set.

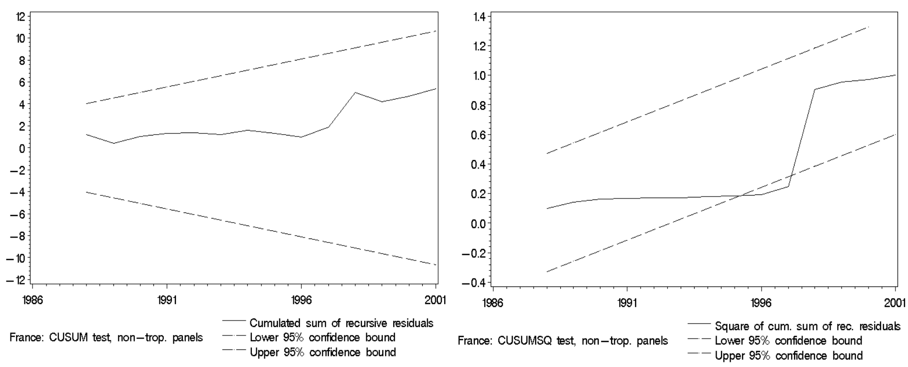

Figure 3.1 Sample plots of the CUSUM and CUSUMSQ tests.

Table 3.4 Outcome of the CUSUM/CUSUMSQ tests performed on the homogenous Translog. C = CUSUM test, CSQ = CUSUMSQ test.

Number of recursive residuals outside 95% bounds, 1962-2001 data set

	France		**Germany**		**Italy**		**Japan**		**UK**		**US**	
Share	C	CSQ	C	CSQ	C	CSQ	C	CSQ	C	CSQ	C	CSQ
TRW					9							1
NTRW				7								
TSW												
NTSW												
TWP								14				
NTWP												
TPU		10				14		2		17		10
NTPU				4								6
TPP		12				4		7		15		2
Sum	0	22	0	11	9	18	0	23	0	32	0	19
											Total	**134**

Number of recursive residuals outside 95% bounds, 1977-2001 data set

	France		**Germany**		**Italy**		**Japan**		**UK**		**US**	
Share	C	CSQ	C	CSQ	C	CSQ	C	CSQ	C	CSQ	C	CSQ
TRW												
NTRW												
TSW					4			1				
NTSW												
TWP												
NTWP		2				5						
TPU						4				7		
NTPU												
TPP								1		1		
Sum	0	2	0	0	4	9	0	2	0	8	0	0
											Total	**25**

Recursive residuals outside 95% bounds, 1977-2001 data set.
The figures refer to the year of the observation.

	France		**Germany**		**Italy**		**Japan**		**UK**		**US**	
Share	C	CSQ	C	CSQ	C	CSQ	C	CSQ	C	CSQ	C	CSQ
TSW					91, 97, 00, 01			90				
NTWP		96, 97				95, 96, 97, 98, 99						
TPU						95, 96, 97, 00				94, 95, 96, 97, 98, 99, 00		
TPP								99		95		

Table 3.5 Outcome of the approximate F-test of imposing the homogenous and symmetric restrictions to the parameters in the Translog.

1962-2001 data set

	France		Germany		Italy		Japan		UK		US	
	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}
Testvalue	3,14	2,88	2,21	-0,21	3,46	0,85	5,17	-0,19	5,63	2,87	4,15	-0,01
F-test, p	0,02	0,02	0,07	-	0,01	0,58	0,00	-	0,00	0,02	0,00	-

1977-2001 data set

	France		Germany		Italy		Japan		UK		US	
	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}	F_{12}	F_{23}
Testvalue	1,97	0,00	1,34	-0,21	2,83	1,72	2,36	0,55	3,07	0,33	2,80	1,05
F-test, p	0,21	1,00	0,37	-	0,11	0,26	0,15	0,80	0,09	0,93	0,11	0,49

3.1.2 Further on model performance

The following text presents the major trends in the remaining part of the tests of the underlying assumptions outlined in section 2.2.4. Unless specified, the results concern the Translog model estimated by the 1977-2001 data set. It should be kept in mind that the analysis comprises estimations of 54 equations; each with 10 explanatory variables and one intercept term. Therefore, the evaluation has to rely upon an overall impression of how the Translog performs. It would not be reasonable to reject the model if a few equations fail to meet the tests, unless the defects are systematic.

In Appendix B, the tables B.1, B.4, B.7, B.10, B.13 and B.16 present the own-price and cross-price elasticities for each of the six countries. The own-price elasticities comprise the 'diagonal elements' and they are in the range – 3,2 to 1,0 with the majority in the range –1 to zero. Therefore, the own-price elasticities are for the most part negative or close to zero, and in less than five instances (out of 60) the own-price elasticities are clearly non-zero and positive.

The dependency of the residuals of each equation to the explanatory (price) variables was tested by simple linear regression. Each equation of the Translog produces residuals, which are tested against the explanatory variables. The residuals are regarded dependent if they prove significant at the 5% level or lower. Table 3.6 presents the outcome of the regressions, and shows little systematic dependency of the residuals to the explanatory variables, although a few variables seem to be problematic in the regressions for Italy and the United States. Table 3.7 presents the tests for multicollinearity, which suggest that multicollinearity is probably not problematic, but still there should be room for further improvements of the model. The outcome of the Breusch-Pagan test of heteroscedasticity will briefly be summed up: Each equation was tested for the 10 explanatory price variables, and none produced significant test sizes at the 5% level or higher.

Table 3.6 Linear regression of residuals on the explanatory price variables. The rows represent the estimated equations and columns refer to the regressions of each country. Significant variables are in the cells with significance levels attached; *=5%, **=1%, ***=0.1%.

	France	Germany	Italy	Japan	UK	US
TRW	NTPU*			TSW*, NTPP*		
NTRW			TPU*			NTRW*, NTWP*, NTPU*, NTPP*
TSW			TSW*, NTSW*, NTPP*	TSW**, TPP*, NTPP*		
NTSW						NTSW*, TWP**, NTPP*
TWP						NTSW*, TWP*
NTWP						TWP*
TPU			TSW*, NTSW*, NTPP*			NTPU*
NTPU						TWP**
TPP			TSW*, TWP*		TPP*	TPU*, NTPU*

Table 3.7 Condition index, test for multicollinearity.

	France	Germany	Italy	Japan	UK	US
Condition index	26,7	24,5	23	20,6	30,6	14,7

The R^2 values and the Durbin-Watson statistics are given in the following two tables. Recall that the regressions are done by differences and not absolute figures, which in most cases bring about lower values of R^2 and stress the usefulness of R^2. The major part of the R^2 values is in the range 0,50 – 0,80 and the Durbin-Watson figures are in the range 1,00 – 3,00 with the majority in the range 1,90 – 2,40.

Table 3.8 R^2 values of the homogenous and symmetric Translog, 1977-2001 data set.

Share	France	Germany	Italy	Japan	UK	US
TRW	0,64	0,27	0,54	0,73	0,53	0,32
NTRW	0,72	0,04	0,56	0,64	0,87	0,97
TSW	0,35	0,30	0,30	0,42	-0,02	0,64
NTSW	0,66	0,76	0,82	0,83	0,26	0,86
TWP	0,34	0,36	0,07	0,43	0,19	0,53
NTWP	0,54	0,61	0,56	0,90	0,60	0,73
TPU	0,72	0,63	0,44	0,59	0,36	0,66
NTPU	0,91	0,84	0,82	0,97	0,82	0,95
TPP	0,50	0,56	0,16	0,36	-0,14	0,25
NTPP	0,70	0,64	0,51	0,91	0,25	0,95

Table 3.9 Durbin-Watson statistics for 1st order autocorrelation. The homogenous and symmetric Translog produces the figures.

Share	France	Germany	Italy	Japan	UK	US
TRW	1,92	1,87	2,00	2,32	1,27	1,14
NTRW	2,66	2,87	1,98	2,64	1,96	1,95
TSW	2,23	2,35	2,22	2,19	2,01	2,20
NTSW	2,26	2,74	2,21	2,03	2,51	1,49
TWP	1,48	2,64	2,19	2,61	3,04	1,86
NTWP	1,74	2,81	1,94	2,07	2,22	1,90
TPU	2,07	1,03	2,22	2,93	2,33	2,55
NTPU	2,47	2,48	2,54	1,95	1,72	1,81
TPP	2,11	2,92	2,33	2,10	1,94	2,46
NTPP	2,30	2,55	2,30	2,43	2,54	2,57

3.2 Parameter estimates

Table 3.10 presents the 90 parameter estimates and the test statistics for the own-price parameters and the cross-price parameters *within* the aggregates. A little more than half of the estimates are significant at the 5% level or better. The insignificant estimates are shaded and the estimates that are significant at the 10% level are highlighted with boxes. Five estimates (5,6%) are significant at the 10% level. The own-price estimates for non-tropical sawnwood (g2222), non-tropical panels (g3232), non-tropical pulp (g4242) and non-tropical papers (g5252) exhibit conformity with respect to magnitude, sign and test power. Furthermore, a good deal of agreement about the insignificant estimates seems to exist too. The number of insignificant estimates is somewhat higher for Germany than the other countries. Table 3.11 presents the 96 cross-price parameter estimates that concern the *between* aggregates relations. Approximately one third are significant at the 5% level or better, and another 10 (10,5%) are significant at the 10% level. Besides the cross-price estimates for non-tropical pulp and non-tropical papers (g4252), there is less agreement about which parameters are significant compared to Table 3.10. In the case of Japan, the number of significant estimates is somewhat higher compared to the other countries.

Table 3.10 Own-price and cross-price (within aggregates) parameter estimates.

	Parameter	France	Germany	Italy	Japan	UK	US
Roundwood	g1111	0.016837	0.000303	0.005005	0.027519	0.000126	0.000028
	p	<.0001	0.5842	0.0010	0.0009	0.4506	0.1070
	g1112	-0.00938	-0.00101	-0.01	0.011497	-0.00035	-0.00002
	p	0.0120	0.6850	0.0245	0.1135	0.4147	0.6705
	g1212	0.099095	0.006886	0.093523	0.061295	0.04537	0.135402
	p	<.0001	0.9199	0.0009	0.0001	<.0001	<.0001
Sawnwood	g2121	0.014823	0.005032	0.036547	-0.01382	-0.01592	0.00106
	p	0.0031	0.2739	<.0001	0.0112	0.0318	0.0080
	g2122	-0.01487	0.001513	-0.00266	0.012517	0.033545	0.000898
	p	0.0185	0.7922	0.7989	0.0297	0.0249	0.0838
	g2222	0.128936	0.104042	0.110818	0.157474	0.14396	0.10852
	p	<.0001	0.0001	0.0003	<.0001	0.0206	<.0001
Panel products	g3131	-0.00131	0.000512	-0.0021	0.009752	-0.00073	0.000599
	p	0.4260	0.6351	0.1885	0.0762	0.9232	0.5107
	g3132	0.0017	0.000852	0.000712	-0.00238	0.008027	0.00037
	p	0.5176	0.6092	0.8054	0.5034	0.2026	0.6952
	g3232	0.048564	0.109933	0.121584	0.059188	0.05406	0.073804
	p	0.0149	0.0002	0.0001	<.0001	<.0001	<.0001
Wood pulp	g4141	0.001708	0.000928	-0.00219	0.000155	0.005522	0.002197
	p	0.2494	0.6288	0.1320	0.7391	0.0811	<.0001
	g4142	-0.00221	0.000669	0.0032	0.002381	0.000822	-0.00028
	p	0.2502	0.7904	0.1465	0.0054	0.8416	0.6161
	g4242	0.126478	0.117092	0.089133	0.116247	0.091875	0.160701
	p	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Paper products	g5151	-0.00017	-0.00178	-0.00039	-0.00081	0.006756	0.001117
	p	0.7976	0.0007	0.6518	0.0794	0.0090	0.0100
	g5152	-0.00258	-0.00011	0.00021	0.000164	-0.00908	1,33E-03
	p	0.2182	0.9156	0.9426	0.8941	0.0657	0.9990
	g5252	0.203842	0.309372	0.186967	0.271032	0.197957	0.25294
	p	<.0001	<.0001	0.0001	<.0001	0.0096	<.0001

Table 3.11 Cross-price (between aggregates) parameter estimates.

	Parameter	France	Germany	Italy	Japan	UK	US
Roundwood-sawnwood	g1121	0.003362	-0.00047	0.005326	0.007	-0.00203	0.000012
	p	0.1135	0.6805	0.0196	0.0089	0.0144	0.7371
	g1122	-0.00171	0.003174	0.007529	-0.00541	0.003707	-0.00009
	p	0.6711	0.1466	0.0723	0.4765	0.0246	0.1841
	g1221	-0.00562	0.008505	0.00402	-0.00086	0.007741	0.000244
	p	0.1913	0.1353	0.6384	0.8123	0.0430	0.4568
	g1222	-0.01981	0.027306	0.015141	-0.0239	-0.03137	-0.02273
	p	0.0775	0.2064	0.3959	0.0367	0.0092	0.0025
Roundwood-panels	g1131	-0.00131	-0.00112	0.000837	0.010254	-0.00016	-0.00002
	p	0.1778	0.0090	0.2211	0.0329	0.7907	0.7473
	g1132	-0.00084	0.001282	-0.0054	-0.00909	0.000332	0.000141
	p	0.8490	0.5789	0.1899	0.0334	0.6817	0.0557
	g1231	0.001364	0.005246	0.00015	0.005534	0.004716	0.001183
	p	0.3967	0.0047	0.9520	0.3637	0.2473	0.0549
	g1232	-0.01045	0.030197	-0.0355	-0.01472	-0.00727	-0.01285
	p	0.3021	0.1715	0.0713	0.0095	0.0970	0.0155
Roundwood-wood pulp	g1141	-0.00542	-0.00095	-0.00291	-0.00126	-0.001	-0.00027
	p	<.0001	0.0627	0.0018	0.0138	0.503	0.0002
	g1142	0.008495	-0.00056	0.004286	-0.00796	0.000037	0.000156
	p	0.0016	0.06407	0.0546	0.0299	0.9582	0.0933
	g1241	-0.00172	-0.00042	0.00614	-0.00132	-0.00171	-0.00004
	p	0.2880	0.8274	0.0635	0.0998	0.4007	0.8804
	g1242	-0.00947	-0.01349	-0.02542	-0.0123	-0.00402	-0.04147
	p	0.2340	0.4613	0.0121	0.0186	0.4003	<.0001
Wood pulp-papers	g4151	0.001521	-0.00027	0.00125	-0.00012	-0.00281	-0.00012
	p	0.0240	0.6759	0.1193	0.6766	0.1471	0.5961
	g4152	0.001334	-0.00266	0.002448	-0.00378	-0.00561	0.00005
	p	0.6527	0.1640	0.4706	0.0005	0.3455	0.9196
	g4251	-0.00006	0.001599	-0.0009	0.001166	0.003159	0.000917
	p	0.9464	0.0923	0.5827	0.1385	0.2668	0.2373
	g4252	-0.07596	-0.06846	-0.04637	-0.05639	-0.0594	-0.0816
	p	<.0001	<.0001	0.0024	<.0001	0.0090	<.0001

3.3 Elasticities

3.3.1 Elasticities by means

The following text presents the elasticities that are computed by the means of the cost shares and therefore expresses the elasticities as means of time period 1977-2001. Emphasis will be on the shadow elasticities of substitution, but a few words on own-price, cross-price and Morishima's elasticities will also be given. Appendix B comprises a complete representation of both.

The own-price elasticities are in the range – 3,2 to 1,0 with the majority in the range –1 to zero. Apart from this, the own-price elasticities are generally higher (more negative) for the tropical products than the non-tropical products when compared within the aggregates. The tables B.1, B.4, B.7, B.10, B.13 and B.16 show that the own-price elasticity of tropical panels is generally close to –1, but close to zero for the non-tropical panels. The same tendency is found for sawnwood, pulp and paper, but not for roundwood. Cross-price elasticities are in the range –1,3 to 1,6 with the majority in the range zero to 1. Apart from this, no patterns seem to exist.

McFadden's shadow elasticities of substitution ranges from – 0,95 to 3,2 with the major part in the range –0,25 to 1,25. For France, Germany and Italy the substitution tends to increase with the level of value added. Japan exhibits a similar pattern, with the exception of roundwood-sawnwood substitution that is somewhat higher. The United Kingdom exhibits more mixed patterns; a little less substitution takes place within pulp and paper and much more substitution appears within roundwood and roundwood-sawnwood. The United States exhibits varying substitution levels between roundwood and the other aggregates, and quite low levels between the pulp and paper aggregates.

A few trends are common to all six countries. First, the substitution between tropical and non-tropical panels is in the range 0,83 to 0,95, which is a moderate level within a quite narrow range. Second, substitution between non-tropical pulp and non-tropical papers is in the range –0,14 to 0,20 for the six countries. Some interesting, but less clear-cut trends should be mentioned. Substitution between tropical and non-tropical pulp is in the range 0,95 go 1,02 for all countries apart from the United States. Substitution between tropical papers and non-tropical papers ranges from 0,99 to 3,1 for France, Germany, Italy and Japan, but goes a low as –0,95 for the United Kingdom and 0,13 for the United States. Non-tropical pulp and tropical paper exhibit a similar pattern. Furthermore, the substitution between tropical pulp and non-tropical paper is in the range 0,97 to 1,00 in all instances, except for the US, for which substitution is negative by –0,57.

Recall that McFadden's shadow elasticities are *symmetric* and that they are computed as a weighted average of the corresponding Morishima's elasticities, which are *asymmetric*. The Morishima's elasticities ranges from –2,9 to 3,2 and have the majority in the range

–1,0 to 1,0. Again, the substitution tends to increase with the level of value added, but compared to the SES the pattern is much more mixed and depends on which of the prices the elasticity is evaluated for. The asymmetric effect is quite marked and sometimes even uniform across the countries, e.g. within panels. For the six countries substitution of non-tropical panels for tropical panels is close to unity if the elasticities are evaluated by the non-tropical prices. However, substitutability is in the range –0,1 to 0,4 if it is evaluated by the tropical prices.

3.3.2 Elasticities over time

The second part of Appendix B presents how the McFadden's elasticities develop over time for each of the six countries. The first five graphs display substitution *within* the aggregates, e.g. non-tropical roundwood vs. tropical roundwood and so forth. The rest of the graphs display substitution *between* the aggregates. Excepting a few, all graphs present one or more cases with unit and constant substitution, which is due to insignificant parameters as explained in section 2.3.4. Trends are less clear-cut in this part of the analysis, but still a few can be identified. In the cases of France, Italy and Japan tropical and non-tropical roundwood substitution declines steadily throughout the period, while substitution converges to unity for Germany, the United Kingdom and the United States (Figure B.1). Apart from Japan, substitution between tropical and non-tropical panels grows slowly, but steadily, from a level around 0,9 in the middle of the 1980s to a level around 0,95 at the end of the period (Figure B.3). Wood pulp substitution is quite constant in the vicinity of 0,8-1,0 except for the United States, which grows markedly in the first half and tends to level off around zero at the end of the period (Figure B.4).

Figures B.6-B.11 display how tropical roundwood substitute for sawnwood, panels and pulp. Around half the elasticities are unity and constant, but the other half exhibit a declining trend apart from two cases. Figures B.12-B.17 present how non-tropical roundwood substitutes for sawnwood, panels and pulp. Contrary to tropical roundwood the picture is more mixed; around half the cases exhibit declining elasticities and approx. a fourth exhibit increasing elasticities. The remainder is unity and constant.

Figure B.18-B.21 present substitution between pulp and paper. Italy and Japan substitutes at a unit and constant level, and in the French case substitution declines and converges to unity. Substitution for the United Kingdom and the United states fluctuates around zero throughout the second half of the period (Figure B.18). Substitution between tropical pulp and non-tropical papers is constant and unity, except in case of the United States where substitution increases and converges to zero (Figure B.19). Figure B.20 shows how non-tropical pulp and tropical paper substitute. In the case of France, Italy and Japan the elasticity is unity and constant, while that of the United

Kingdom and the United states fluctuates around zero from 1990 and onwards. For all countries, non-tropical pulp and non-tropical paper substitution fluctuates around zero and within a narrow range (Figure B.21).

3.4 Comparison with other studies

Barbier *et al.* (1994) quotes a 1988 study by Constantino for short run and long run elasticities of substitution between temperate and South East Asian origin of sawnwood and plywood. The time period is 1975-1985. Constantino's paper could not be accessed, and therefore the comparison must rely on the scarce information given by Barbier *et al.* and the following assumptions:

- Constantino's definition of sawnwood resembles the one for sawnwood used here
- Plywood is comparable with the current aggregate of wood based panels
- South East Asian origin is comparable with tropical origin in this study
- Constantino's temperate origin is comparable with the one for non-tropical origin here

Table 3.12 Comparison of substitution elasticities.

Aggregate	**Constantino (1975-1985)** Short run	Long run	**SES range in the current study (1977-2001)**
Sawnwood	1,30	2,11	–0,77 – 2,36
Wood based panels	0,75	1,23	0,83 – 0,95

Uusivuori & Kuuluvainen (2001) applies a Translog cost function in the analysis of FAOSTAT data for 1990-1997, and estimates own-price and cross-price elasticities in the global imports of roundwood. The paper distinguishes tropical hardwoods from softwoods, and under the assumption that these aggregates are comparable to tropical and non-tropical roundwood in the current study, the following comparison of Morishima's elasticities of substitution (MES) can be made. Give the suffix 1 to tropical hardwoods, the suffix 2 to the softwoods, and recall that the MES is the difference between the cross-price and the own-price elasticities.

Table 3.13 Substitutability between tropical roundwood and softwood.

Aggregates and direction of substitution	Uusivuori & Kuuluvainen (1990-1997) Cross-price elasticity	Own-price elasticity	Implicit MES	MES range in the current study (1977-2001)
Evaluated by tropical round-wood prices	η_{12}=0,12	η_{22}=–0,92	MES_{12}= 1,04	–0,60 – 1,00
Evaluated by softwood prices	η_{21}=0,92	η_{11}=–0,84	MES_{21}= 1,75	–0,19 – 1,00

Furthermore, Uusivuori & Kuuluvainen (2002) applies a Translog cost function, 1980-1997 FAOSTAT data and estimates own-price and cross-price elasticities in the Japanese import of roundwood from Africa, Chile, Malaysia, the United States and a group of other countries (Table 3.14). Let Malaysia represent tropical origin and Chile the non-tropical origin and find the following comparison based on the same principles as above.

Table 3.14 Substitution in Japanese roundwood imports.

Aggregates and direction of substitution	Uusivuori & Kuuluvainen (1980-1997) Cross-price elasticity	Own-price elasticity	Implicit MES	Japanese MES in the current study (1977-2001)
Evaluated by Chilean origin	η_{12}=–0,02	η_{22}=0,34	MES_{12}= –0,36	0,56
Evaluated by Malaysian origin	η_{21}=–1,27	η_{11}=–0,66	MES_{21}= –0,62	0,32

Vincent *et al.* (1991) applies a Generalised Leontief specification of a profit function and Japanese trade statistics in the analysis of price relations within sawlogs from North America, the USSR and the ‘South Seas’ (Malaysia, Indonesia, the Philippines and Papua New Guinea) (Table 3.15). The study estimates own-price and cross-price elasticities for two periods; 1971-1978 and 1979-1987. If sawlogs are compared to the roundwood aggregate of the current analysis and the ‘South Seas’ reflects tropical origin and North America the non-tropical origin, the following comparison can be produced.

Table 3.15 Comparison of Morishima´s substitution elasticities.

Aggregates and direction of substitution	**Vincent *et al.*** Time period	Cross-price elasticity	Own-price elasticity	Implicit MES	**Japanese MES in the current study (1977-2001)**
Evaluated by North American origin	1971-1978	η_{12}=–0,06	η_{22}=0,44	MES_{12}= –0,50	0,56
	1979-1987	η_{12}=–0,11	η_{22}=0,51	MES_{12}= –0,62	
Evaluated by South Seas origin	1971-1978	η_{21}=–0,15	η_{11}=0,10	MES_{21}= –0,25	0,32
	1979-1987	η_{21}=–0,19	η_{11}=0,19	MES_{21}= –0,38	

3.5 Elasticity changes

Section 2.3.2 presented how changes of the elasticity of substitution can be related to the relative price. However, a total of 126 shadow elasticities have been estimated, and it will not be feasible to address each one of them. Instead, the following two graphs are presented as examples of how the elasticity and relative price may interact. Figure 3.2 displays the steady decline in the substitutability of tropical and non-tropical panels, while the relative price seems to fluctuate around unity. In this case the curvature changes in the sense that the isoquant tend to ‘bow inwards’. Figure 3.3 displays how substitution elasticity between tropical roundwood and tropical sawnwood declines along with a decline in the relative price. In this case, the substitution elasticity seems to change in response to the relative price, which can be interpreted as a movement along the isoquant.

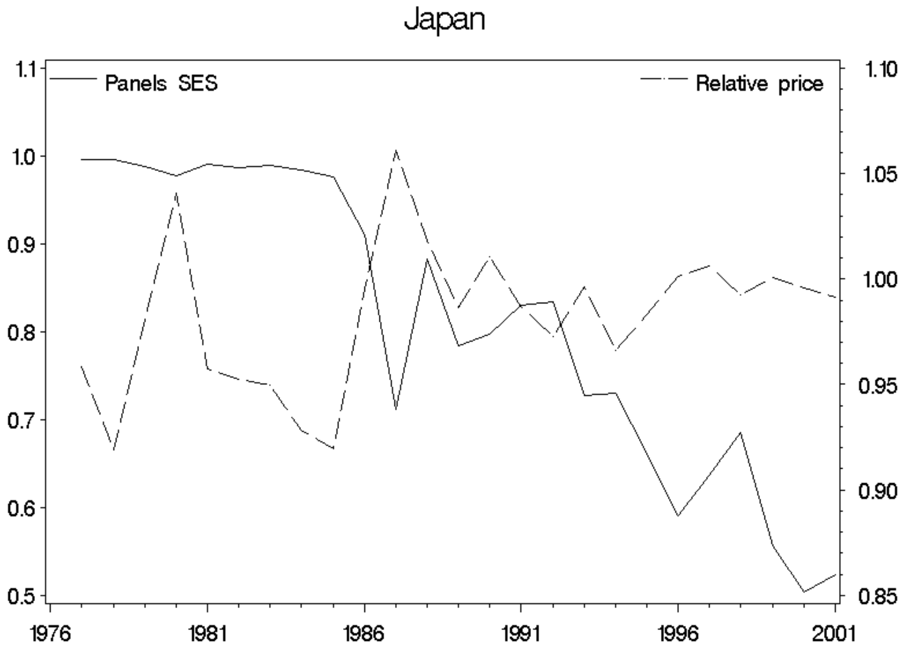

Figure 3.2 Tropical and non-tropical panels substitution and the corresponding relative price for Japan.

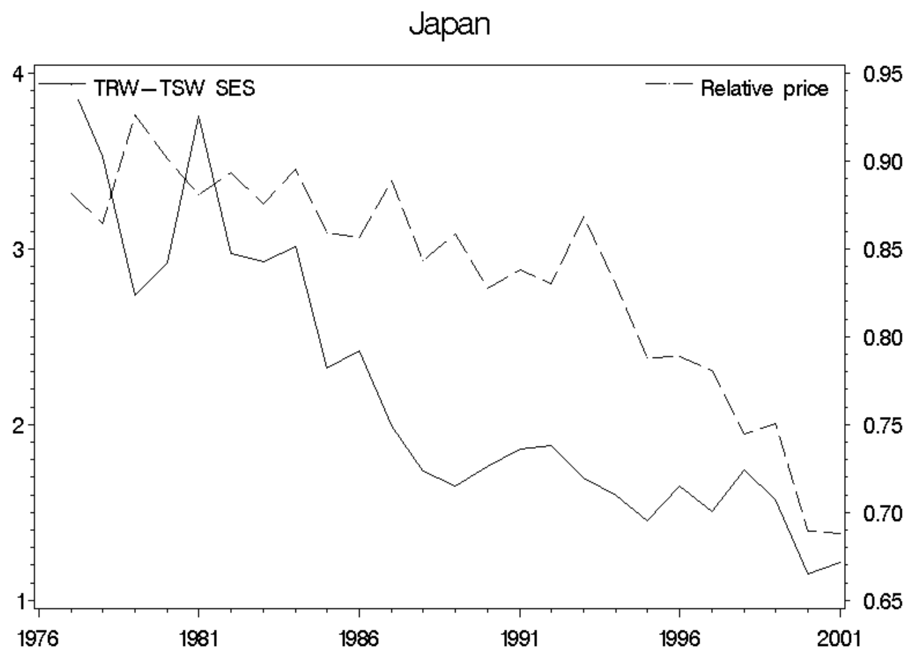

Figure 3.3 Tropical roundwood and tropical sawnwood substitution and the corresponding relative price for Japan.

3.6 Impact of parameter significance

As mentioned in section 2.3.4 the evaluation of how the elasticities develop over time may be sensitive to the level of significance required for the parameter estimates. The following example is based on the German figures of how tropical roundwood and tropical wood pulp substitute. Three parameters are involved: g1111 (p>0,58), g1141 (p>0,063) and g4141 (p>0,63). In the initial estimation, none of the parameters are included, because they all exceed the 5% limit, which produces a unit and constant SES. In the second estimation the 10% limit is accepted, and the third estimation is unrestricted. The outcome is presented in Figure 3.4 and clearly demonstrates that accepting the higher limits may produce quite a different outcome than the 5% limit.

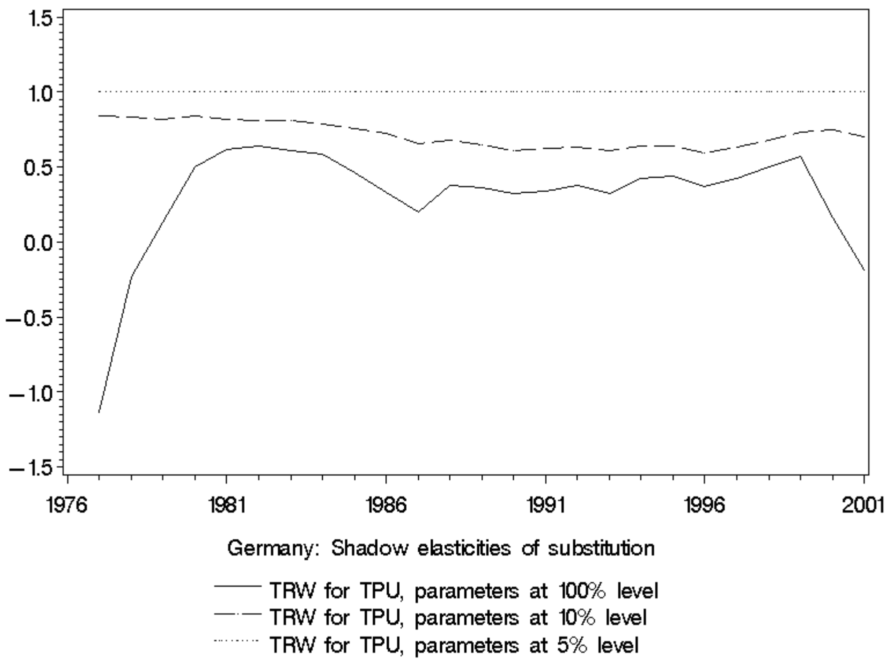

Figure 3.4 SES estimation with different requirements of parameter significance.

4 Discussion

The first part of this chapter discusses a selection of the assumptions that follow from the choice of methods and materials. The second part discusses the use of the elasticity of substitution and the results. The discussion aims at the central assumptions and issues that may affect the understanding and use of the analysis.

4.1 Methods and materials

4.1.1 Cost shares

The cost shares express apparent consumption and assume that the tropical imports are fully consumed by the importing country and that exports concern exports of domestic non-tropical manufacture only. This implies a systematic over-estimate of the tropical cost shares, which cannot easily be corrected because the re-export figures are not available. However, there are good reasons to believe that the over-estimates are not immense. According to Barbier *et al.* (1994) the primary directions of the tropical timber trade are from South-East Asia to Japan, from Africa to Europe and from South America to North America. Trade across these patterns takes place of course, but the magnitudes are much smaller than the primary routes. It can be argued that the internal European trade may cause distortions to data, e.g. Marseille in France is known as the European port for tropical roundwood, while Rotterdam in Holland is the primary gate for panel imports. On the other hand, if the country of origin is duly specified during the import procedures, transit should not disturb the quality of data. However, this cannot be taken for granted, just as it was not possible to clear out how transit information are passed on from the European countries to FAOSTAT. Contrary to the re-export issue, illegal imports of tropical wood products may cause a systematic underestimate of the tropical cost shares, especially in case the tropical wood products are classified as non-tropical origin. For good reasons, the character and the magnitude of the illegal trade is uncertain, but there should be no doubt that it takes place. Many tropical countries enjoy tariff reductions or exemptions, which points to a limited advantage of deliberate misclassification of tropical wood imports. On this bases, it seems reasonable to assume that the illegal imports mostly concern banned wood species in the form of roundwood and sawnwood and perhaps panels, but not as pulp or paper. If this is true, quantities are probably small, but the unit values may be high, and therefore the overall effect of the illegal trade is probably limited, but biased towards the less value added commodities.

In sum, some data disturbance must be accepted, but the effects may very well offset each other, and it is therefore believed that the data set provides a useful representation of the trade flow and consumption.

4.1.2 Prices

Prices are computed as the import values divided by the import quantities for tropical and non-tropical origin of each aggregate, and as a result prices are net of import tariffs. This approach to prices introduces a number of assumptions. First, the reader should realise that the applied FAOSTAT aggregates are '1st order' aggregates or 'as high as can be'. Each one of them aggregates a number of four-digit aggregates in the Harmonised System for customs classification (HS). Application of such aggregates implies that the price estimates cannot be observed in 'real life'. It is therefore assumed that each country responds to prices that are not 'real', but on the other hand, the cost shares have the similar characteristics. It can therefore be argued that the high level of aggregation may 'blur' data to such an extent that no real effects are observed. However, application of '2nd order' aggregates (aggregates of six-digit aggregates in the HS) may be just as delicate, because the structure has changed over time, which implies that the '2nd order' aggregates are not fully comparable before 1985, e.g. FAO (1994), Michie & Wardle (2002). For more recent data, and therefore shorter time series, '2nd order' aggregates are interesting because they are 'one step closer to real life', but for the purpose of complex analysis they suffer from relatively few observations. In principle, constructing panel data sets accommodates for the lack of observations, but even at the six-digit level, the aggregates are not fully comparable across countries because the consumption patterns differ. Comparability increases if '3rd order' data (eight digits) are employed, but these time series may be even shorter than six digits and not all of those are available from FAOSTAT.

The second implicit assumption that follows from the application of (customs) trade statistics is that tariffs are irrelevant to the proportions of domestic production, trade and consumption, and therefore the relative sizes of the cost shares. This is clearly a critical assumption, but as it will emerge from the following, taking tariffs into account is not easily done and may introduce a bias, just as ignoring them. The effect of a tariff can be analysed in terms of Figure 4.1, which builds on Kjeldsen-Kragh (2001), pp. 15-17. The abscissa measures the quantity of the domestic consumption and the ordinate measures the price, S is the supply curve and D the demand curve. Suppose that the importing country is 'a small country' that cannot affect the word price level, P_W. Without a tariff domestic production will be 0A and imports AB. Imposing a tariff, T, the domestic price level will rise to P_W+T, making domestic production 0C and imports CD, with an overall decrease in consumption. In this case, excluding tariffs introduces a systematic underestimate of the import prices and therefore the cost shares of the imports. In case the importing country is a 'large country' that can affect the world prices, imposing a tariff depresses P_W and the domestic market would face a price somewhere in between P_W and P_W+T. The six importing countries can be regarded as three entities, Japan, the United States and the European Commu-

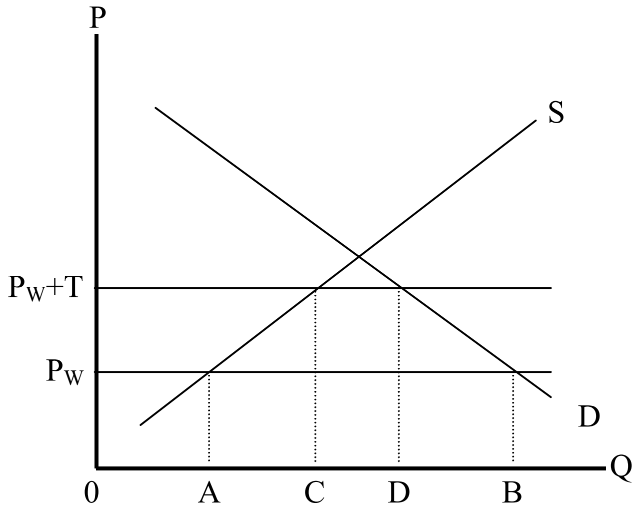

Figure 4.1 The effect of a tariff in a one-commodity (partial) model.

nity, which are all known for being able to affect world prices. When the tariffs are not accounted for, the cost shares are systematically underestimated by the size of the tariff rates. However, this bias concerns both tropical and non-tropical origin and it requires detailed knowledge to say if the *relative* sizes of the tropical and non-tropical cost shares are biased by the tariffs. Moreover, the tariffs tend to increase with the level of value added (tariff escalation). For this reason, the relative sizes of the cost shares are biased in the sense that the cost shares of the value added commodities are underestimated compared to the less value added ones. Furthermore, this bias reduces as the tariffs are reduced, which has happened several times during the concerned time period.

Due to the large country effect, the prices in the data set (observed at the borders) may be depressed by the tariff rates. When the tariffs are reduced the large country effect causes that the buyers may perceive a price change that is zero or smaller than the tariff reduction, because the sellers (exporting countries) tend to increase the prices by the size of the of the tariff reductions. This implies that the price changes in the data set may differ from the price changes that the buyers observe. However, as the tariffs are reduced, the data set price changes converges to the price changes that are observed by the buyers. Finally, it should be kept in mind that the tariffs change over time and that the changes are often asymmetric across countries, e.g. Barbier *et al.* (1994), ITTO (1997). No doubt, additional knowledge, e.g. in form *level of protection indexes*, may improve the basis of the analysis, but such indexes have not been identified.

It can be concluded that the exclusion of tariffs from the analysis may introduce an underestimate of some cost shares. On the other hand, there are good reasons to believe that the bias is more or less offset because the importing countries depress the world prices. In conclusion, the bias concerns both tropical and non-tropical origin, but it is not easy to judge if the bias is balanced between the two groups.

4.1.3 Exchange rates

The effects of exchange rates are not addressed by the analysis. All trade values are measured in current US$ and converted into real prices by application of a price index. This is consistent as long as imports are traded in US$ and the domestic currency is US$, which narrows it down to the majority of the Unites States trade. Furthermore, the rational can be extended to include Japan, because the Japanese Yen correlates closely to the US$. In case of the European countries, a majority of the tropical imports are traded in US$, but a good deal of the non-tropical imports are not, e.g. the inter-European trade. The European currencies float freely against the US$ most of the time. This implies that the real prices of the non-US$ trade flows may be distorted by the conversion into US$ in the sense that they may not fully reflect how the real prices are perceived by the European consumers. It should be clear that similar to the tariffs, the effects of exchange rates are complex to capture, and it requires additional knowledge to what has been included so far to assess these effects.

4.1.4 The tropical non-tropical distinction

The distinction between tropical and non-tropical origin is a central feature of the analysis, and as explained in section 2.4.2, the distinction reflects a technical and a geographic-economic distinction, viz. short vs. long fibres and developed vs. developing country origin. It can be argued that this distinction is not fully consistent, and that other distinctions would be more interesting or will become so in the future. The tropical countries of this paper are listed in Table 2.3. The table presents countries that are not considered as developing countries or major tropical wood products exporters today, e.g. Taiwan, Hong Kong, Singapore and South Korea. However, the time series dates back to 1962 and at that time the situation was different from today. Moreover, there is no reason to believe that any of the tropical countries should be considered to have switched status from tropical wood products exporters to non-tropical. So in these respects the definition seems operational. The definition may exhibit another defect, though. In case the tropical goods are processed in transit outside the tropics and consumed in one of the six importing countries, the use of this definition should be re-considered. This scenario is not considered a major problem in the current analysis as the definition of tropical countries is wide, but it must be acknowledged that the most recent development in China questions the use of the definition. As explained in section 2.4.1 China is now the world's largest importer of tropical roundwood, and a major part of this roundwood is processed into plywood (panels) that are re-exported, e.g. to Japan Johnson *et al.* (2003). China is considered a non-tropical exporter, and it can therefore be argued that the Japanese imports of tropical panels are underestimated in the last years of the analysis. This is merely a question of definitions, but if we return to measuring the competitiveness of developing countries, it must be realised that changing trade patterns may distort the analysis. An alternative could be employment of a GDP measure as definition of developing country, but this is less operational because it requires that the country status would be evaluated at each year to be fully consistent with the purpose. Furthermore, the informative value of a GDP measure is highly debatable, because it measures the formal economic sector only. In many countries the informal economic sector may account for as much as the formal sector, and moreover, the relative size of the informal sector varies across countries.

4.1.5 Separability structure

The separability structure is presented in Figure 2.5 and further elaborated in Figure 2.6. The structure of the analysis (10 equations with 10 explanatory price variables) requires a fairly high number of observations to produce reliable estimates. The structure can be regarded as an 'overkill' when considering that only 21 substitution elasticities out of 45 are identified as interesting, cf. Section 2.5.1. For this reason, it would be attractive to gain degrees of freedom by a simpler structure that separates demand further. Figure 2.6 shows that the demand for roundwood is related to the demand for sawnwood, panels and pulp, while the demand for papers is related to the demand for pulp only. If papers were excluded or weighed together with the pulp aggregate, the structure would be reduced to an '8x8' structure. However, this would incur a loss of insight into the interactions between the timber industry and the paper industry, unless investigated by a separate model. The study by Simangunsong & Buongiorno (2001) is the only one that takes the paper industry into account, even though the paper industry may very well be the largest single consumer of virgin wood fibres. Bolton (1998) reports that in 1995, the paper industry used 650 million cubic meters of wood to produce pulp, exclusive of 100 million tonnes of waste paper. Foresters probably know that the forest, timber and paper industries are related via the production of roundwood as presented in Figure 2.6, but few seem to address the possible implications for the assessment of roundwood consumption. This probably reflects how the industries are organised; forest, timber and paper have their own organisations, but nevertheless, there seems to be a lack of holism when it comes to the economic modelling. The other studies that are presented in Section 3.4, address the '2nd order' aggregates, e.g. industrial roundwood, pulpwood and plywood. This approach assumes that the different ‘2^{nd} order’ aggregates are separable from each other, which may be approximate. The consequence of applying such aggregates is clear from Section 3.4 as the lengths of the time series are 8, 10 and 18 years respectively. ‘1^{st} order’ aggregates are comparable since 1962.

Figure 2.5 shows that secondary processed wood products like furniture and builders carpentry are excluded from the analysis. Such data are not available from FAOSTAT and this is probably the reason why none of the other studies address the secondary products. EFI-WFSE provides data for the trade in a number of secondary products, but these time series are not of equal length and concern trade only, not domestic production. In general, domestic production figures are difficult to access unless they are highly aggregated. Some figures can be accessed though, e.g. from the EUROPROMS[5] database. However, the time series are relatively short and data are not fully comparable with the trade statistics at the four and six-digit levels in the HS. EUROPROMS data are comparable to the eight-digit level in the European Combined Nomenclature (CN), but the HS and the CN are not fully comparable at the eight-digit level, only at the four and six digits, cf. Danmarks Statistik (2004). Obviously, the exclusion of secondary products may bias the outcome, because the cost shares may respond to the prices of the secondary products also, which are outside the current model. Furthermore, the bias may increase as labour intensive processes are outsourced to developing countries. On the other hand, taking secondary products into account would be quite complicated because of the data limits.

4.1.6 Model performance

The Translog was subjected to a series of consistency tests, and the overall impression of the results presented in Section 3.1 suggests that the Translog performs well. It can therefore be assumed, that the logarithmic relationship between relative prices and cost shares provides a useful model of the interactions at a highly aggregated level. Parameter stability was improved significantly by excluding the first 15 observations from the data set, which is an especially important feature with respect to the quality of the elasticities.

However, the Translog exhibits some degree of autocorrelation. Table 3.2 shows that a majority of the equations are significant at the five and one percent levels, and in some cases even at the 0.1 percent level. Autocorrelation occurs op to the fifth order. It is debatable if five or one percent significance justifies an intervention, because any such incurs a trade off in terms of degrees of freedom. But significance at the 0.1 level and the many significant lags speak in favour of adding dynamic elements to the Translog. The SAS macro language

[5] EUROPROMS is a EUROSTAT database that comprises production and trade statistics in industrial products since 1993.

easily introduces autoregressive (AR) or moving average (MA) processes of a given order, but it is has proved almost impossible for the iteration to converge. In terms of the Durbin-Watson statistics, autocorrelation does not seem to be a major problem to the Translog, but this concerns first order autocorrelation only, not higher orders. The Durbin-Watson statistics suggest that first order autocorrelation may be positive as well as negative, which indicates that there may be more than one cause of the problem (cf. Table 3.9). True autocorrelation suggests that the cost shares or residuals depend on a lagged structure. One interpretation would be that it requires more than one period (year) for the cost shares to adjust to price changes. This sounds appealing, but it would probably require a series of rather complex estimations to prove it. Since the cause of the autocorrelations has not been identified, it is not easy to judge the implications for the estimates. In case the functional form is not appropriate, the estimates may be biased. In case the model lacks an autoregressive process, the significance levels are not fully reliable. Some degree of uncertainty about the estimates must therefore be accepted.

The first 15 observations were excluded on the basis of a structural change test (CHOW test, Table 3.3). Moreover, the CUSUMQ tests indicate another structural shift in the middle of the 1990s (Table 3.4). However, such a structural shift is not encountered for two reasons. First, structural shifts are delicate to introduce to systems of equations, because it cannot be taken for given that all dependent variables require a shift at the same time. Second, apparently the SAS MODEL procedure does not allow for the estimation of a system of equations that includes a structural shift. This implies that only the homogenous Translog can be explored.

The condition indexes are presented in Table 3.7 and suggest that there should be room for improving the Translog with respect to multicollinearity, although it should be stressed that the problem is probably limited to moderate. Ideally, the condition indexes should be as close to zero as possible and not exceed 30. In the current analysis most indexes are in the range 20-30, which suggests that one or more explanatory variables are redundant and should be excluded or combined with another variable. Reducing multicollinearity stabilises the estimates with respect to data fluctuations, which is an attractive feature. Furthermore, a lower condition index would make it easier to introduce other explanatory variables for testing other hypotheses.

As a supplement to the formal tests, it should be noted that the own-price elasticities are non-positive for the most part. In half of the cases it follows from the insignificance of the own-price parameter estimates, which are set to zero (cf. Table 2.1 and Table 3.8). Nevertheless, non-positive own-price elasticities suggest that the Translog is well behaved with respect to concavity, which is an important feature of cost functions.

4.2 Results

4.2.1 The elasticity of substitution

The application of substitution elasticities has two arbitrary elements that should be absolutely clear to the user. First, in the two-factor case, substitution elasticities are always non-negative; it simply follows from computation technique. However, in the more-than-two-factor case, negative substitution elasticities may arise. As explained in Section 2.3.3 negative substitution elasticities are termed complementary behaviour and imply that increased use of one factor input is associated with increased use of the other factor input. There should be no problem with this, although the interpretation may seem less straightforward than for the non-negative. A simple example is the farmer who employs labour, tractors and fuel. In case the farmer substitutes tractor use for labour use, she would require more fuel to run the tractor. If this scenario is analysed by a three-factor model, tractor-labour substitution is positive and tractor-fuel substitution negative. But, in case the scenario is separated into two two-factor models, both substitution elasticities become positive, and it follows that the two-factor analysis is restricted from modelling complementary behaviour. This example clarifies the interdependence between substitution elasticities and the separability structure discussed in Section 4.1.5. For this reason, the reader must decide on the separability structure, before the substitution elasticities can be interpreted in a meaningful way. The '10x10' structure of the current analysis is certainly capable of modelling complementary behaviour, and this is an important feature with respect to the analysis of how the elasticities develop over time. Over a 40 or 25 years time span it is quite likely that pairs of factor inputs may be substitutes at one time and complements at another. Such nuances would enrich the debate about the effects of trade regulation.

The second arbitrary element is the classification of factor inputs as substitutes or complements by either Morishima's measure (MES) or McFadden's measure (SES). Recall from Section 2.3.3 that the MES is a two-factor-one-price substitution elasticity that is asymmetric in most cases ($MES_{ij} \neq MES_{ji}$.) As pointed by Chambers (1994), it follows from the asymmetry that the classification may depend on which input price changes. For this reason, Chambers argue that McFadden's measure provides "… a more complete measure of relative input responsiveness." However, the SES is a weighted average of the corresponding MES, and therefore it can be argued that information is lost by application of the SES instead of the MES. Furthermore, if the magnitudes of the cost shares differ much, $S_i \ll S_j$, the SES becomes very close to MES_{ji}. This is quite relevant for the current analysis, because the tropical cost shares are much smaller than the non-tropical cost shares. So on the one hand, the MES is a more informative measure than the SES, but on the other hand, the SES has more 'holistic' measure.

So far the use of substitution elasticities have been centred on the appraisal of trade regulations, but hopefully, it is obvious to the reader that there are other just as interesting applications of substitution elasticities. For example, the tropical non-tropical distinction is interesting with respect to changes in comparative advantages like labour salaries, technology, forest management regimes and exchange rate regimes.

4.2.2 Elasticities by means

Own-price elasticities are generally negative, which suggest that consumption is sensitive to the own-prices. Moreover, the tropical own-price elasticities are generally higher (more negative) compared to the non-tropical. The literature provides no explanation for this phenomenon, but it is quite interesting for two reasons. First, *ceteris paribus*, in terms of the Morishima's substitution elasticities, substitutability is higher when it is evaluated by the tropical prices, cf. Table 2.1. Furthermore the phenomenon is interesting because it can be interpreted in different ways. One explanation would be that tropical products have the characteristics of being luxury goods compared to the non-tropical. The rationale is based on the fact that tropical timber products are generally more expensive than non-tropical timber products. However, the rationale cannot be extended to pulp and paper. Another reason could be that the non-tropical products are processed on more capital-intensive machinery than the tropical products. In such a case stable supplies that keep the machinery going may be just as important as the price of the input, because 'downtime' is extremely expensive to capital-intensive productions. Still, this rationale does not capture the relatively high own-price elasticities of the tropical pulp and paper, because paper manufacture is capital intensive no matter what the origin of the fibres may be. In case of pulp and paper, the relative magnitudes of consumption may provide an explanation. E.g. in 2001 Japan consumed close to 10 million tonnes of pulp, of which tropical pulp accounted for less than a half million tonnes. Such proportions suggest that the tropical pulp manufactures are price takers more than the non-tropical manufactures. In sum, it can be argued that the difference in magnitudes of tropical and non-tropical own-price elasticities has more than one cause.

With the exception of the United States, McFadden's shadow elasticities of substitution increase with the level of value added. This may not come as a big surprise, e.g. it sounds reasonable that Mahogany logs and Spruce logs compete less than A4 printing paper from Brazil and Germany. But never the less, the finding is quite important to development processes because it confirms that the desirable 'down stream' development incurs an increased exposure to competition. The development of a competitive environment relies on many structures that are outside forestry and the processing industries, e.g. infrastructure and stable economic and political environments. If these prerequisites are not met, development projects aimed at 'down stream' processing are likely to fail, especially if they are targeted at competitive exports markets.

Across all countries the SES of the panels is close to unity, which seems to confirm that tropical and non-tropical panels are true competitors. Similar patterns are identified for pulp and paper, but with a few exceptions, though. These cases are good examples of how the information derived from Morishima's and McFadden's measures may differ. If the same relations are analysed in terms of the MES, the asymmetry immediately becomes clear. In almost all instances, substitutability is relatively high when tropical prices change, and relatively low when non-tropical prices change. In the first case the substitution elasticities are generally unity, but in the range zero to 0.3 in the second case. No explanation for this marked behaviour has been identified, but the above small vs. large manufacturer discussion may be applicable here as well. The findings suggest that the tropical panel, pulp and paper have less 'competitive power' than the non-tropical, and this is very relevant for the issue of further trade liberalisations. Trade liberalisations are, for the most part, synonymous with tariff reductions and abolishing of quotas, which in itself is desirable because it brings about welfare gains. However, a number of developing countries are already favoured via the Lomé Convention and the GSP arrangement, and further tariff reductions will therefore be a disadvantage to these countries. It requires no substitution elasticity to reach this conclusion, but the information derived from the SES and MES confirm that many developing countries will be adversely affected by trade liberalisations. In addition to this, the asymmetry of the MES highlights two issues. First, that in case of tariff reductions that are equal across tropical and non-tropical origin, the tropical products will benefit less than the non-tropical products. Second, the asymmetry suggests that in case of the tropical products, competitiveness is more than just prices.

Substitution elasticities *between* aggregates of different processing orders, e.g. roundwood-sawnwood, measure the willingness by which the importing countries may outsource or 'home-source' the different production processes. This part of the analysis comprises 32 MES and 16 SES, but only a few trends are addressed. In general, substitutability is in the range 0.5 to 1.0 and complementary behaviour occurs in approximately every tenth case. But there is much variation across the countries, which probably reflects that the countries exhibit different comparative advantages and processing traditions. The tendency seems to be that tropical panels and tropical pulp substitute for roundwood more easily than the non-tropical panels and pulp do. This probably follows from the declining imports of tropical logs across most countries (cf. Figure A.1-A.10). The pulp and paper substitution is generally close to unity, and this is also the case when it comes to the paper aggregates, e.g. tropical paper for non-tropical paper. This finding suggests that the importing countries will buy from the most competitive source. However, if the same relations are analysed in terms of MES, it becomes clear that tropical pulp and paper are generally less competitive than non-tropical origin.

4.2.3 Elasticities over time

This part of the discussion focuses on the analysis and application of time varying substitution elasticities in terms of the SES only. It is not the aim to discuss the implications of each one of the trends that can be identified from Figure B.1 to B.21. Instead, a general discussion is given and the text goes through one case that exemplifies important issues.

The analysis is affected by the insignificant parameters that are set to zero because they make the SES go to unity and exhibit very little variation. Section 3.6 and Figure 3.4 clearly demonstrate the sensitivity to the significance levels of the estimates. This is an unfortunate feature of the analysis, because the significance limits are arbitrary and the levels may be affected by the degrees of freedom, but that is statistics. Strictly speaking, insignificance is not a proof of the true value being zero, instead we cannot say if the true value differs from zero, and it is for this reason that the estimates are set to zero. In line with this, it cannot be concluded that the SES are unit and constant because the estimates are insignificant, we just cannot tell if they differ from unity. Figure B.1 to B.21 display a lot of variation over time, and on basis of this there is no reason to believe that the true SES would be unit and constant, just because the estimates are insignificant. However, in the particular case of the Translog, if the true values of the estimates are zero, the Translog reduces to the Cobb-Douglas form, which suggests that any change of the relative price is fully offset via substitution at any time. Unit substitution elasticity makes perfect sense, but in the light of the variation elsewhere, it is difficult to accept that substitution should be constant as well. In terms of substitution elasticities, the Cobb-Douglas is clearly a less flexible functional form than the Translog. However, the flexibility of the Translog is debatable when it is taken into account that the 'default' is the Cobb-Douglas. For this reason, it can be argued that insignificant estimates are not desirable in the Translog. The argument can be extended to suggest that the Translog suffers from a weakness when it comes to modelling time variation of substitution elasticities that are close to unity. Figures A.85 to A.96 leaves no doubt that the cost shares vary over time, but it follows from the computation technique (Table 2.1) that significant estimates are required to introduce the variation into the elasticities. With respect to significance, true values that are close to zero require relatively smaller standard errors than true values that clearly differ from zero, *ceteris paribus*. For this reason it requires 'better data' for the Translog to capture the variation of substitution elasticities that are close to unity. It can be suggested that due to the many parameters and the high level of data aggregation, the 10% significance limit should be accepted. However, as presented in Table 3.10 and 3.11, the number of significant estimates does not change much as a result of this in the current analysis, which indicates that the outcome is robust in this regard.

Figures B.1-B.21 leaves no doubt that substitution elasticities change over time, and that in many cases the change is systematic. Systematic change suggests that substitution elasticities that are computed as means over time suffer from systematic error. In case projections or forecasts rely on assumptions about constant substitutability, the systematic error is introduced this way. Furthermore, systematic change suggests that elasticities can be modelled and introduced into projections as a functional relationship, which reduces the systematic error. Only a few figures display trends that are even across all countries, e.g. Figure B.17 and B.21, but many figures present trends that are common to half of the countries or more, e.g. Figures B.1, B.3 and B.13. Common trends suggest that elasticities may be estimated by panel data sets, but on the other hand anti-trends exist too and suggest that panel data should be employed with care. Anti-trends imply that substitution elasticities of one country or region should not be applied to other countries without additional knowledge.

4.2.4 Changes to the elasticity

Whenever change occurs, the analyst would probably like to know why. Recall from Section 2.3 and equation (16) that the substitution elasticity is basically a product of changes to a ratio of factor inputs and a ratio of factor input prices, which implies that both quantities and prices may cause elasticity changes. As a point of departure, agents are expected to react to price changes, which in terms of Figure 2.1 incurs a movement along the isoquant. This movement changes the ratio of factor input and in most cases the elasticity as well (Figure 3.3). However, the following text will show that prices are not always the cause of change.

The substitution between panels presented in Figure B.3 is quite stable over time, and apart from Japan there seems to be a minor upward trend. In the case of Japan, substitutability declines steadily from the mid 1980s and onwards. This case was analysed in relation to the relative price (cf. Figure 3.2), which suggests a change of taste or technology because the relative price is stable. As discussed in Section 4.1.4 a part of the explanation may be that Japan has switched an increasing part of its imports to Chinese origin, which is in the non-tropical group. On the other hand, Figures A.13 and A.15 show that since the late 1980s, tropical panels have gained marked shares in Japan. This finding is interesting in two respects; it supports the notion of a change of taste, and it confirms that substitution takes place even though the substitutability declines. According to Peck (2001), in the

1980s Japan commenced a switch from domestic conversion of tropical logs into panels to imports of panels manufactured closer to the forest resources, viz. Indonesia and Malaysia. The switch was most likely initiated by the increasing number of tropical countries that have contracted roundwood exports by bans or tariffs, e.g. Barbier *et al.* (1994). This is probably the true reason for the increased tropical market share, because the Japanese domestic manufacture is defined as non-tropical in the current analysis. The example highlights some import features. First, change of substitution elasticity can be for other reasons than prices, and additional information may be required to understand the causes. Second, the substitution elasticity strictly measures substitutability, and it should not be confused with the physical substitution that actually takes place. Third, definitions of origin may confuse the interpretation of the change. The Chinese, Indonesian and Malaysian panels are made from tropical logs just as the Japanese panels were, and therefore the technical properties have not changed much.

4.2.5 Comparison with other studies

Tables 3.10 and 3.11 compare a selection of the results with two other studies. The comparison technique is debatable, because the aggregates are not identical and a part of the analysis relies on a manipulation of one study. On the other hand, the literature leaves very little room for comparing anything, and if the technique is accepted the outcome shows no conflict between the current study and those quoted. It should be kept in mind that the comparison concerns a very little selection of the overall output of the current analysis, but it lends support with a little stretch. These tables suggest that different levels of aggregation may not affect the elasticities much. Moreover, Table 3.11 indicates that employment of trade (import) figures instead of apparent consumption data may not change the outcome significantly. This points in the direction that application of FAOSTAT or EFI-WFSE data may bring about similar outcomes. The latter notion is supported by Figure C.2, which compares a selection of FAOSTAT and EFI-WFSE trade data. The figure shows that even though the figures may differ substantially with respect to absolute figures, they follow the same trends.

Table 3.12 concerns Japanese consumption of roundwood, and shows that the outcome of the paper by Uusivuori & Kuuluvainen (2002) differs from the current analysis with respect to sign. This finding is interesting because the functional form and data source are comparable to what have been employed here. The study by Uusivuori & Kuuluvainen (2002) is specific with respect to country of origin, which suggests that aggregation across countries may affect the outcome.

Table 3.13 concerns the Japanese import of sawnlogs, which has been compared to the roundwood aggregate of the current paper.

Vincent *et al.* (1991) applies a Generalised Leontief specification of a profit function and Japanese trade statistics, and they produce an outcome that differs from what this analysis finds. This suggests sensitivity with respect to methodology, but on the other hand, this author will not emphasise the study by Vincent *et al.* (1991) much, because it recognises a problem with the model performance. The problem is acknowledged with regard to the own-price elasticities, which are all positive.

5 Conclusion

In terms of McFadden's shadow elasticity of substitution, the substitutability of the tropical and non-tropical wood products is generally positive and increases with the level of value added. With respect to increasing the export earnings from wood products sale, this finding suggests that the further down stream the processing is moved the better. In terms of Morishima's measure, the classification of the products into substitutes or compliments becomes two-sided. In general, the substitutability is close to unity when it is evaluated by the tropical prices, and close to zero when it is evaluated by the non-tropical prices. This finding implies that the tropical exporters are able to capture market shares by lowering the prices, which is in opposition to the non-tropical producers. Application of Morishima's measure therefore suggests that down-stream processing is an attractive path to increased export earnings, if the tropical exporters are able to improve their competitiveness in terms of prices.

The analysis finds that there are few unconditional answers to the question of how the tropical countries will be affected by further trade liberalisations. In general, the tropical panel exporters that currently enjoy tariff advantages are those who will be negatively affected the most. Tropical sawnwood exporters are less bad off, because sawnwood substitutability is generally lower than for panels. The positive substitution elasticities between products of different processing orders suggest that the importing countries are generally open to outsourcing. This finding indicates that if the most competitive manufactures are outside the tropics, the level of in-transit conversion in non-tropical countries may increase as a consequence of tariff reductions.

The study presents the delicacy of the employment and interpretation of the elasticity of substitution. The different measures answer different, but closely related questions, and the outcome may be sensitive to the separability structure, the functional form and data. Nevertheless, the results of the current analysis converge with the findings of previous studies, and this supports the current outcome. In many cases, the elasticities change systematically over time, which indicates that the constant means-over-time elasticities suffer from systematic error. Systematic change suggests that the elasticities should be introduced into projections as a functional form. Basically, changes to the substitution elasticity are induced via prices or quantities or both. However, the case of the Japanese panel imports clearly shows that knowledge beyond this may be required to understand the true reasons for the changes.

6 Perspectives

The overall issue that this study addresses is forest resource endowments and their utilisation. On a global scale, forest products are big business that concerns the welfare of millions of people in most parts of the world. The issue is very complex and for this reason it is close to inexhaustible in terms of research. As discussed in Chapter four, there is much valuable knowledge to be realised from improved analysis of the international trade in wood products. In example, the impacts of trade distortions are far from thoroughly quantified, even though they are extremely relevant to issues like distribution of wealth and conversion of forests to farmland etc. In line with the current analysis, there remains much insight to be gained about how wood products compete. The current analysis and most of the quoted studies address highly aggregated data. This is appropriate to macro levels like policy-making, but the generated knowledge should not be applied to micro levels like development projects or investment analysis without strong reservations. For those purposes, analyses of less aggregated data like the 8-digit levels in the HS/CN are desirable. Furthermore, if the tropical non-tropical distinction is maintained, such models may gain substantially from a three-sector structure in terms of a domestic, a foreign non-tropical and a tropical sector. However, such models are probably future talk because data is limited and difficult to access.

In terms of the current analysis, a number of interesting improvements have been pointed at. E.g., the existence of a time-lagged structure has an intuitive appeal because it sounds reasonable that consumptions patterns change with a delay to price changes. If time lags exist, it implies that the full effects of changes of comparative advantages are delayed also. Additionally, two major deficiencies are identified: The exclusion of China and the secondary processed wood products. China is important for the understanding of an in-transit conversion that may develop to be a major issue for years onwards. The inclusion of secondary processed products is required to understand the impact of outsourcing to the demand for the lesser value added products. Nevertheless, this author believes that the current study contributes with new and interesting insight to the trade in tropical wood products. Specifically, the employment of the Morishima’s measure of substitutability provides interesting nuances, viz. that substitutability is more sensitive to changes in the tropical prices than changes in the non-tropical prices. The finding that substitutability increases with the level of value added seems trivial at first. However, it confirms that moving the production down-stream is comparable to a two-edged sword; the unit values increase, but the exposure to competition increases as well.

Appendix A – Data I

The amount of data is substantial, and in order not to leave the reader with a 'Black box' feeling about it, this appendix presents data in graphs. The Appendix comprises three parts: Apparent consumption, Prices and Cost shares. Apparent consumption is computed as production minus exports plus imports for each year. The graphs present *accumulated* quantities in cubic meters for the aggregates Roundwood, Sawnwood and Panel Products and in metric tonnes for Pulp and Paper Products. Prices are presented as current prices and deflated or real prices. Real prices are derived from the current prices by Fisher's ideal index computed for each country. Cost shares are computed as each commodity's share of the overall costs each year. The graphs *accumulate* the cost shares for tropical and non-tropical origin respectively.

Appendix contents:

6.1 Apparent consumption

6.1.1 France

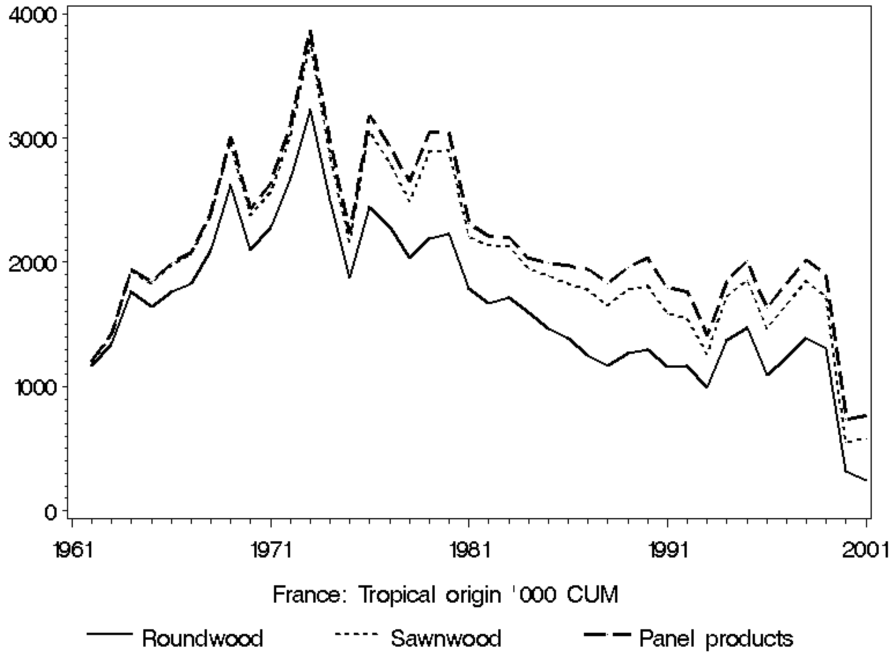

Figure A.1 Apparent consumption of tropical roundwood, sawnwood and panel products.

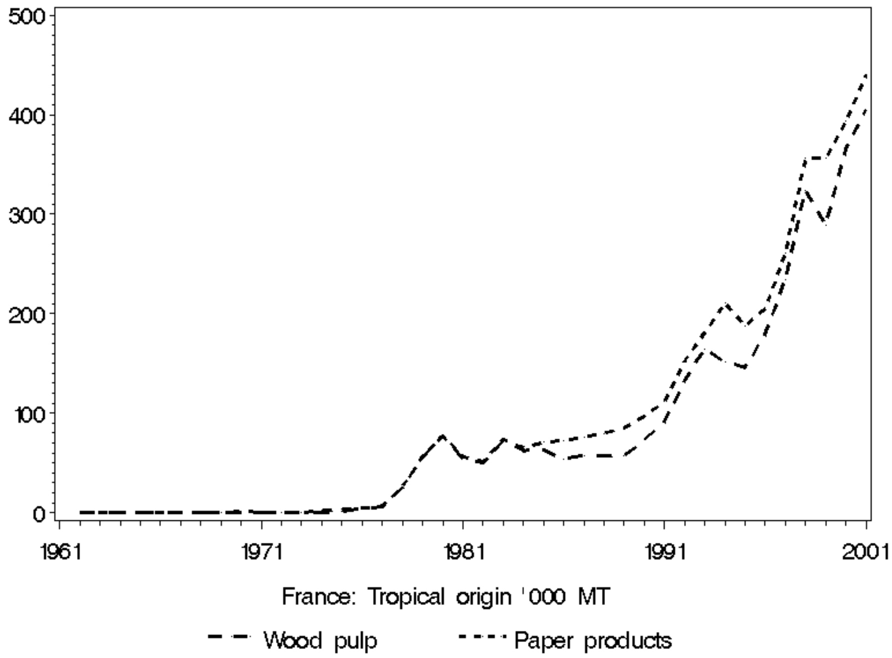

Figure A.2 Apparent consumption of tropical pulp and paper products

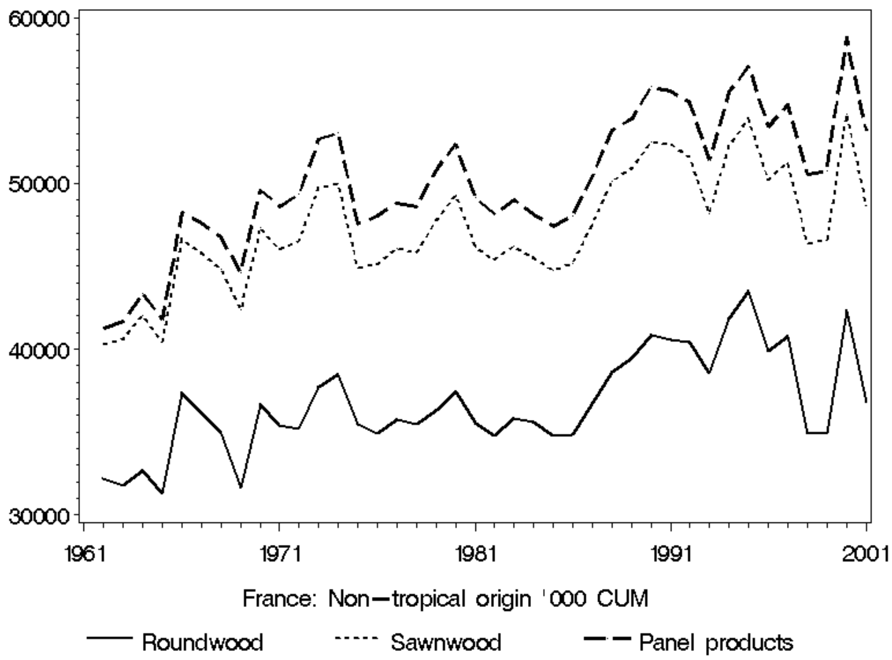

Figure A.3 Apparent consumption of non-tropical roundwood, sawnwood and panel products.

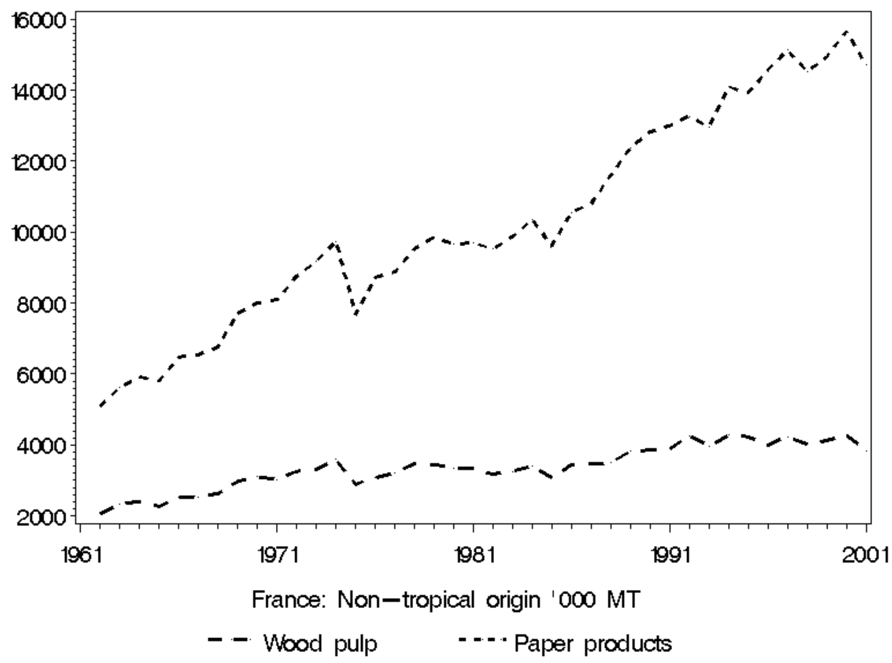

Figure A.4 Apparent consumption of non-tropical pulp and paper products.

6.1.2 Germany

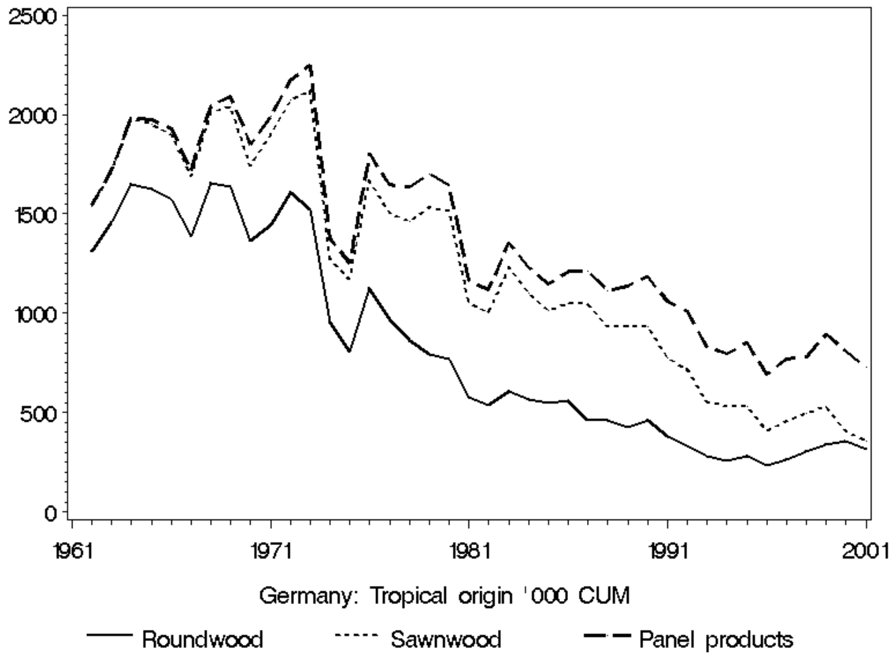

Figure A.5 Apparent consumption of tropical roundwood, sawnwood and panel products.

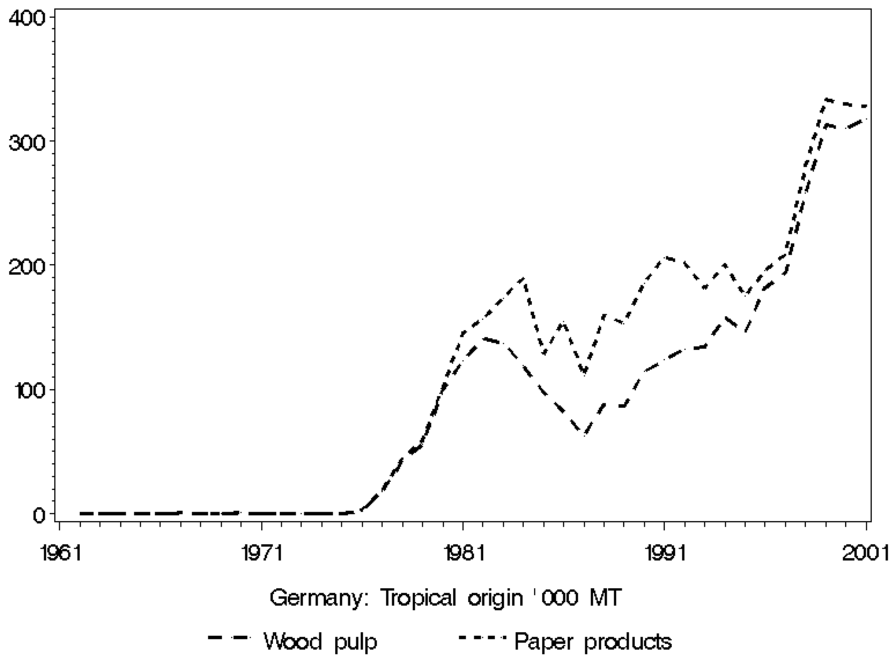

Figure A.6 Apparent consumption of tropical pulp and paper products.

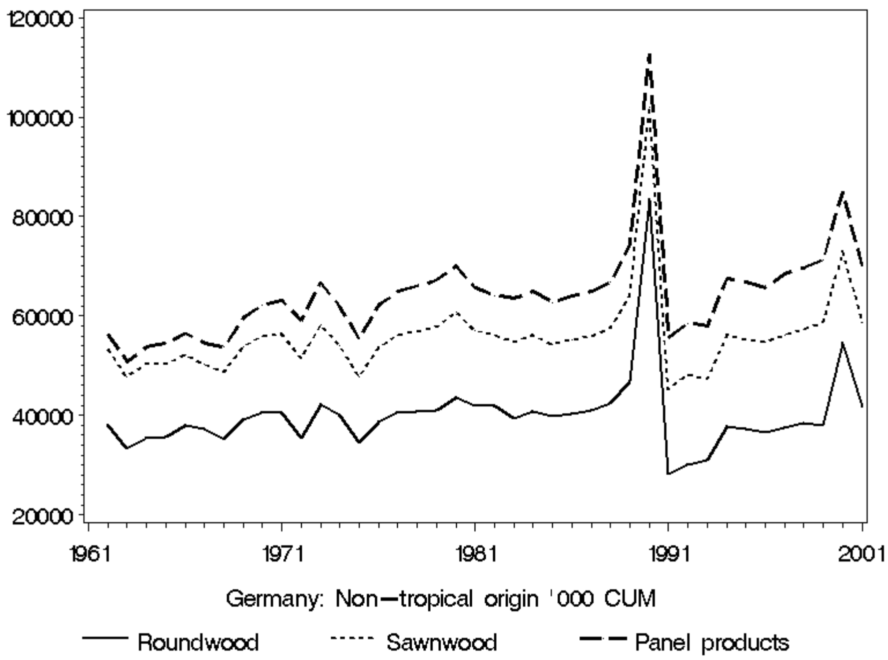

Figure A.7 Apparent consumption of non-tropical roundwood, sawnwood and panel products.

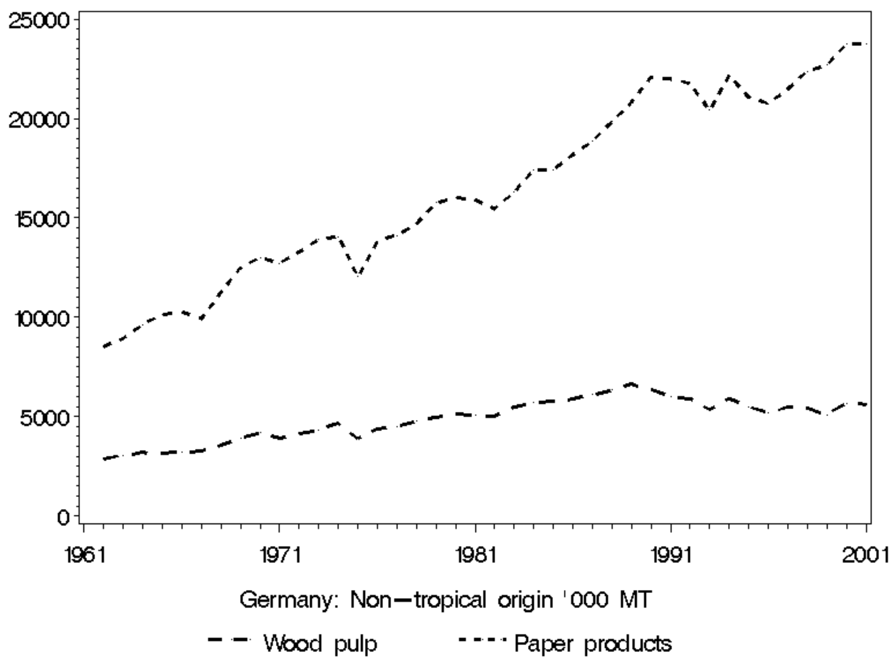

Figure A.8 Apparent consumption of non-tropical pulp and paper products.

6.1.3 Italy

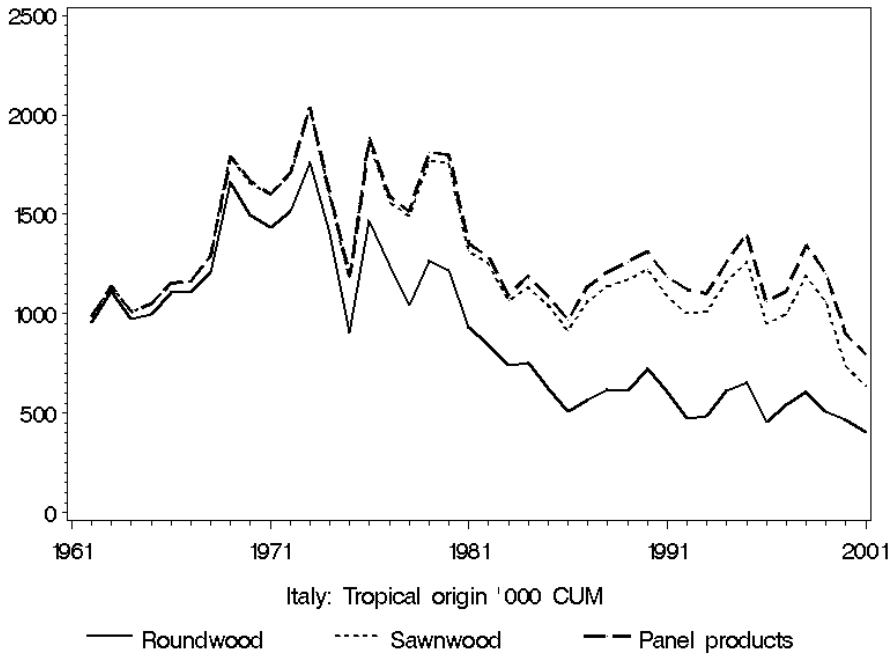

Figure A.9 Apparent consumption of tropical roundwood, sawnwood and panel products.

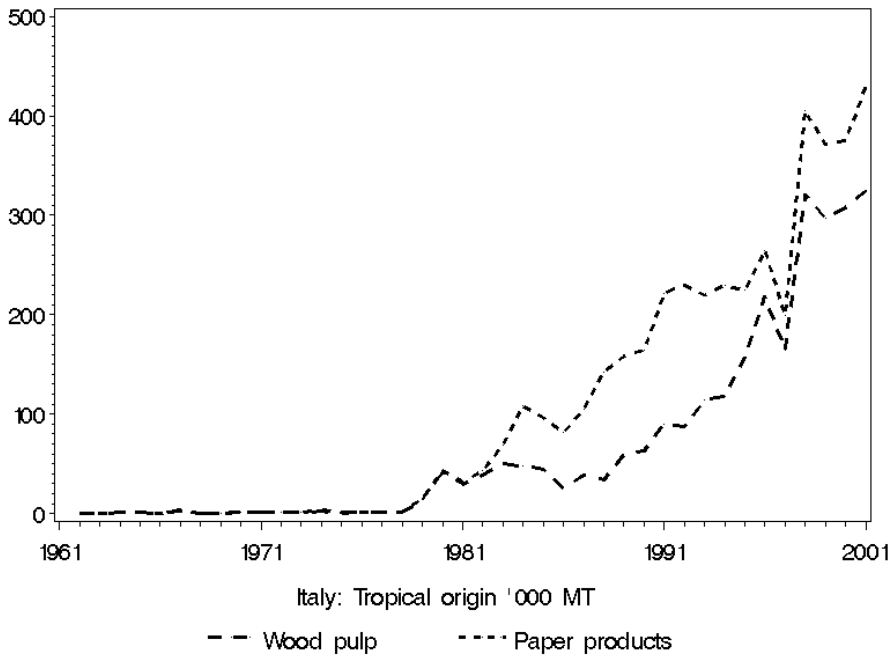

Figure A.10 Apparent consumption of tropical pulp and paper products.

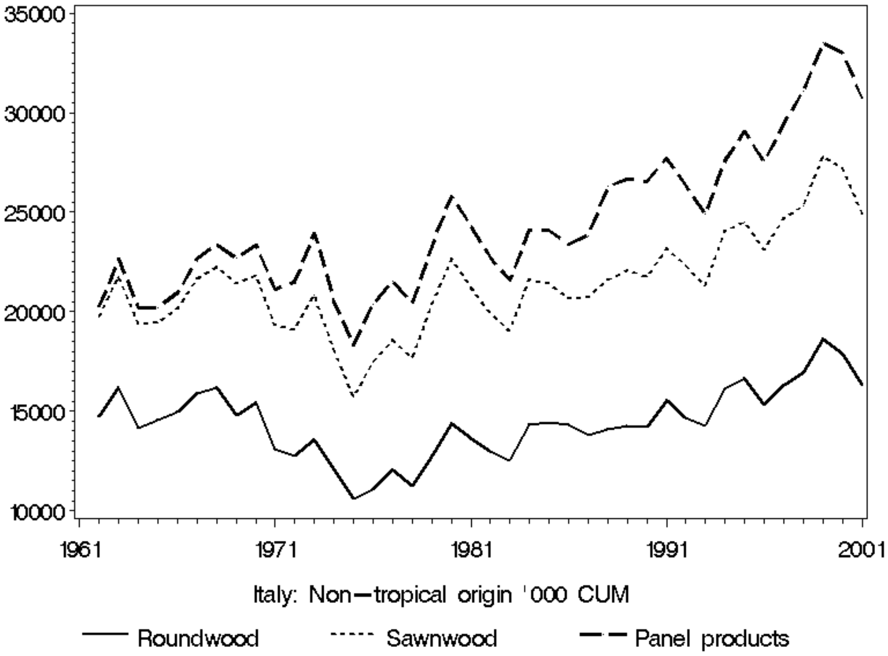

Figure A.11 Apparent consumption of non-tropical roundwood, sawnwood and panel products.

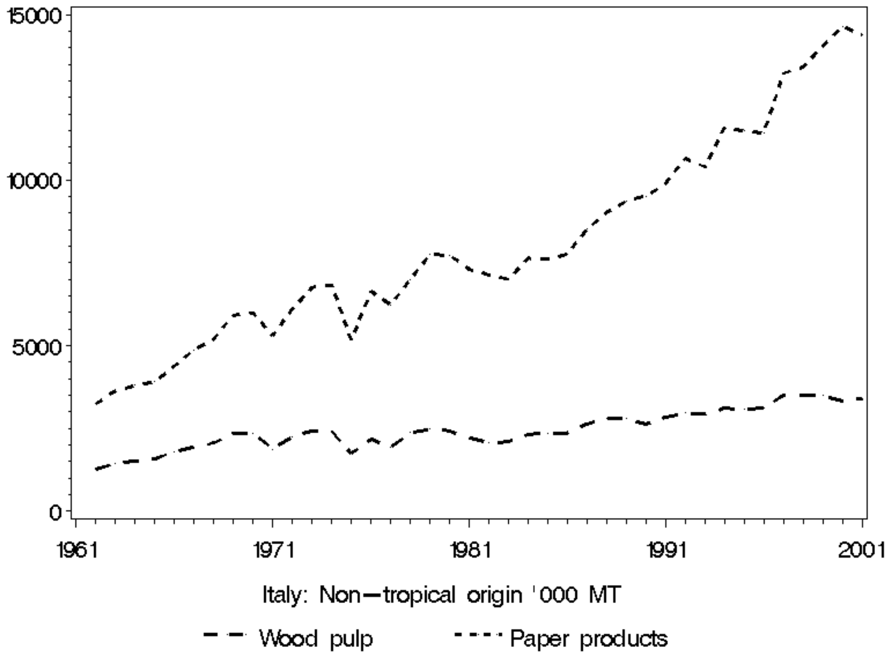

Figure A.12 Apparent consumption of non-tropical pulp and paper products.

6.1.4 Japan

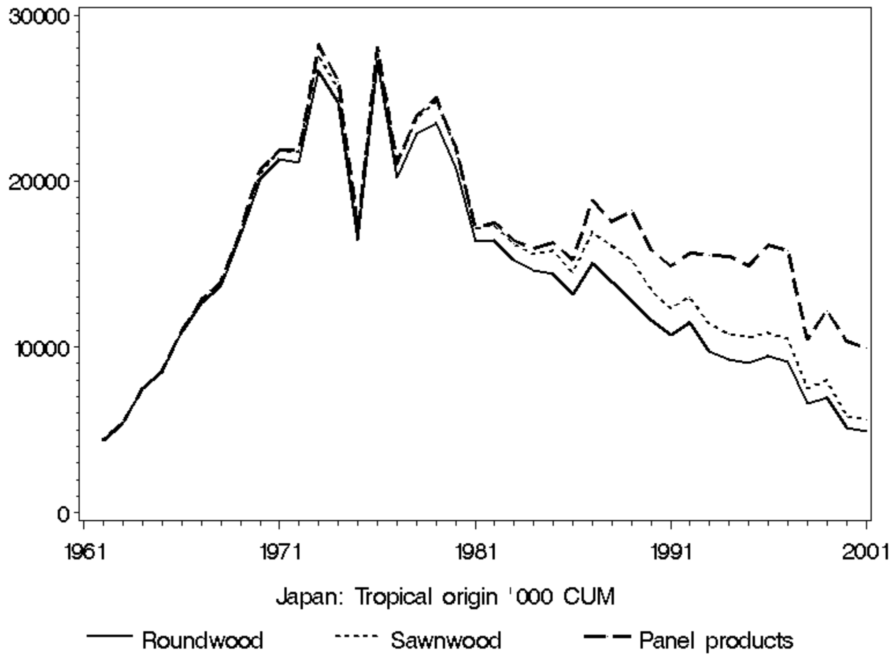

Figure A.13 Apparent consumption of tropical roundwood, sawnwood and panel products.

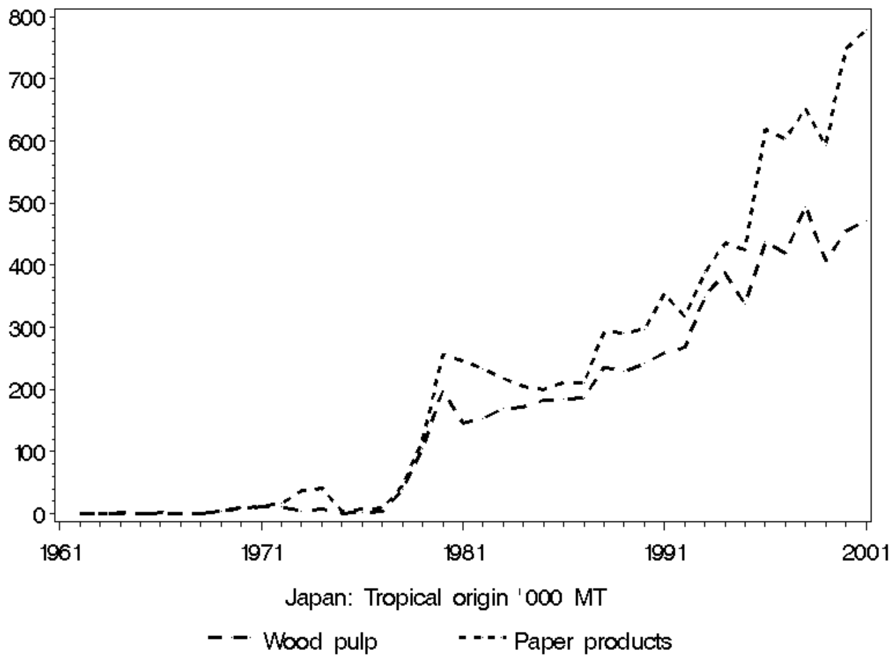

Figure A.14 Apparent consumption of tropical pulp and paper products.

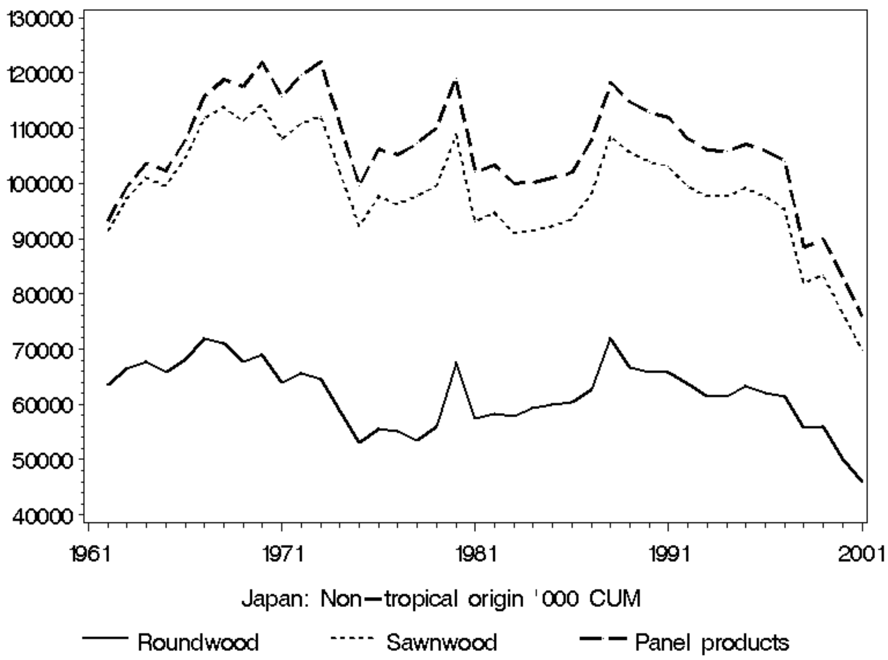

Figure A.15 Apparent consumption of non-tropical roundwood, sawnwood and panel products.

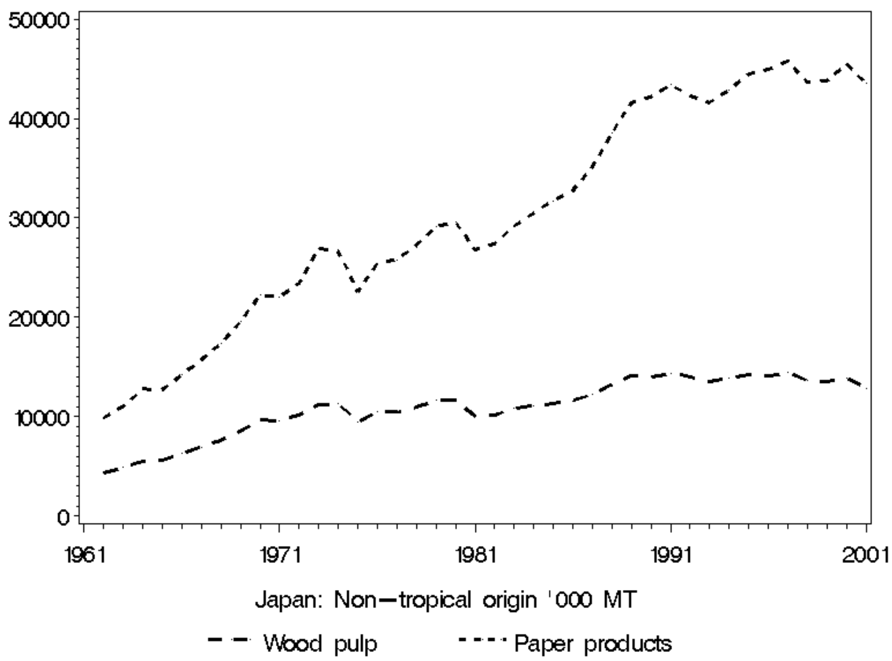

Figure A.16 Apparent consumption of non-tropical pulp and paper products.

6.1.5 United Kingdom

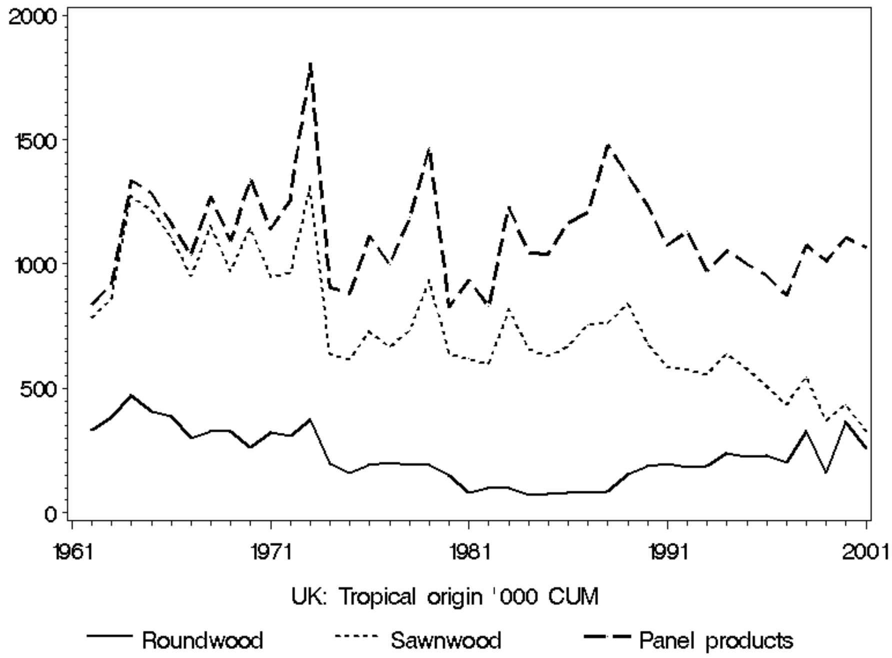

Figure A.17 Apparent consumption of tropical roundwood, sawnwood and panel products.

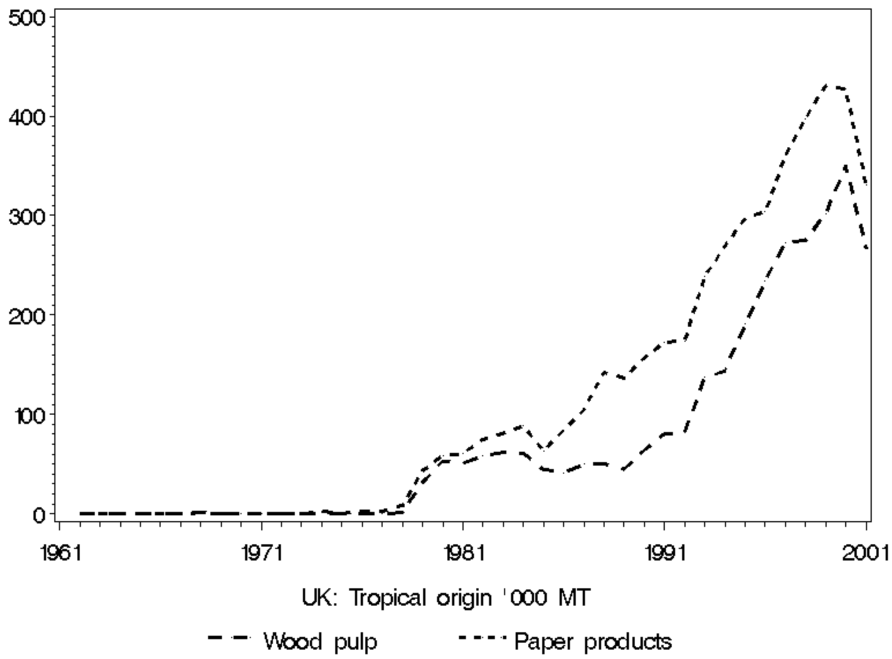

Figure A.18 Apparent consumption of tropical pulp and paper products.

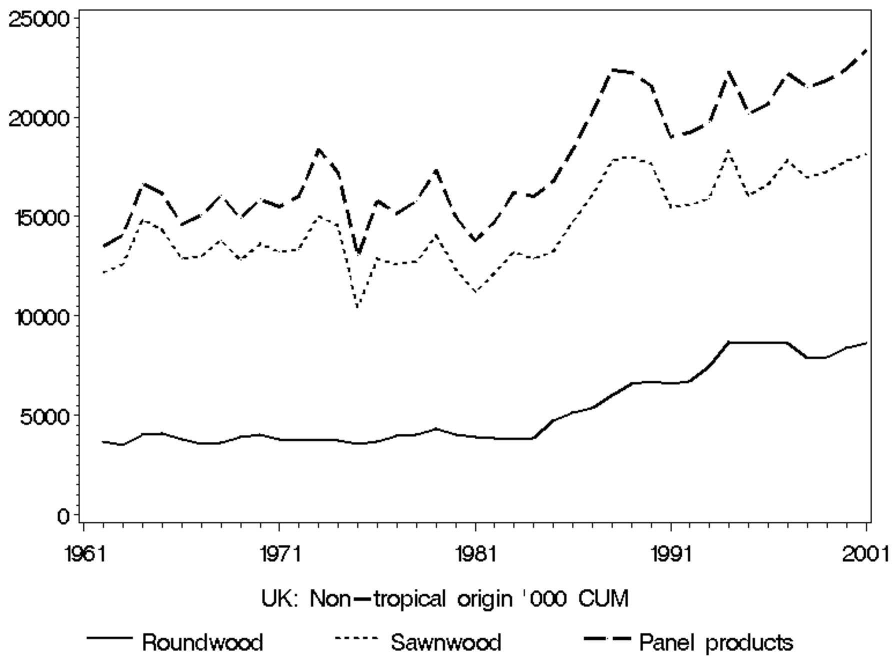

Figure A.19 Apparent consumption of non-tropical roundwood, sawnwood and panel products.

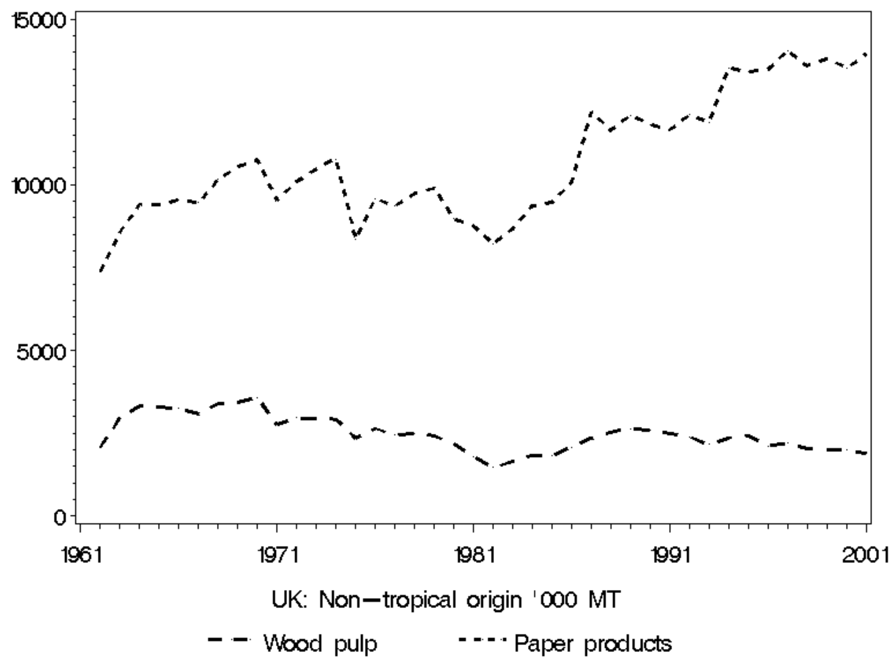

Figure A.20 Apparent consumption of non-tropical pulp and paper products.

6.1.6 United States

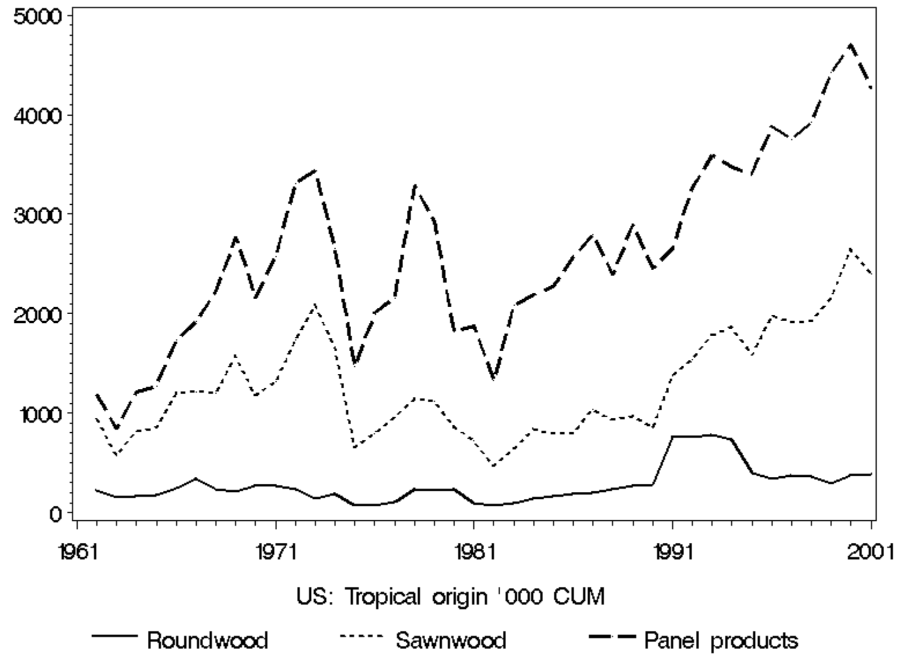

Figure A.21 Apparent consumption of tropical roundwood, sawnwood and panel products.

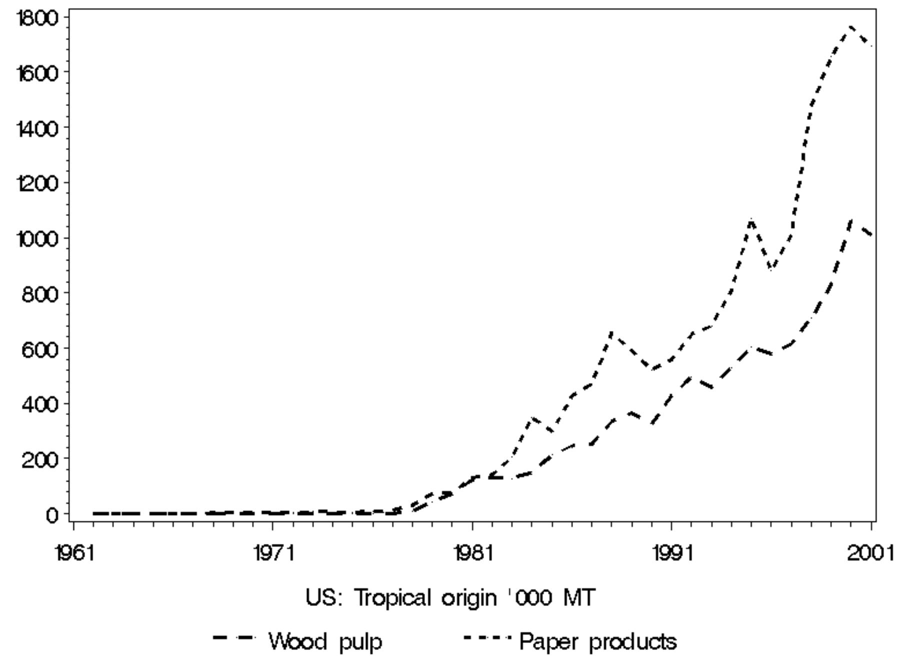

Figure A.22 Apparent consumption of tropical pulp and paper products.

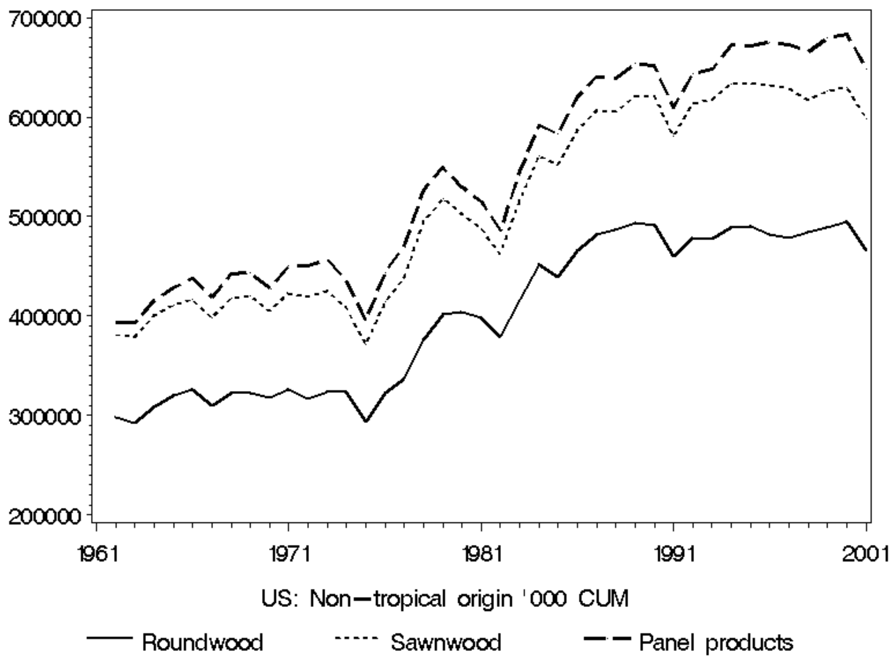

Figure A.23 Apparent consumption of non-tropical roundwood, sawnwood and panel products.

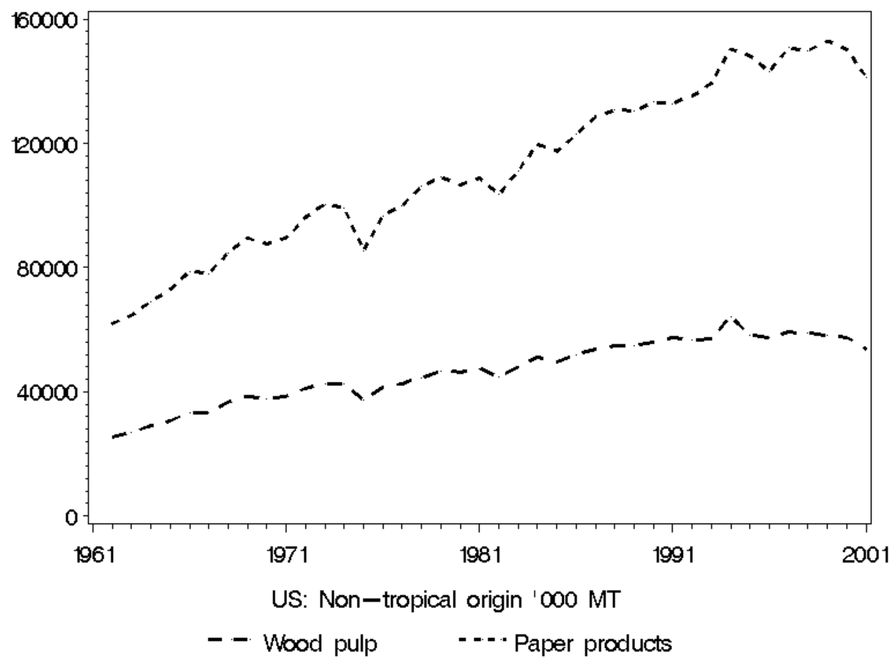

Figure A.24 Apparent consumption of non-tropical pulp and paper products.

6.2 Prices

6.2.1 France

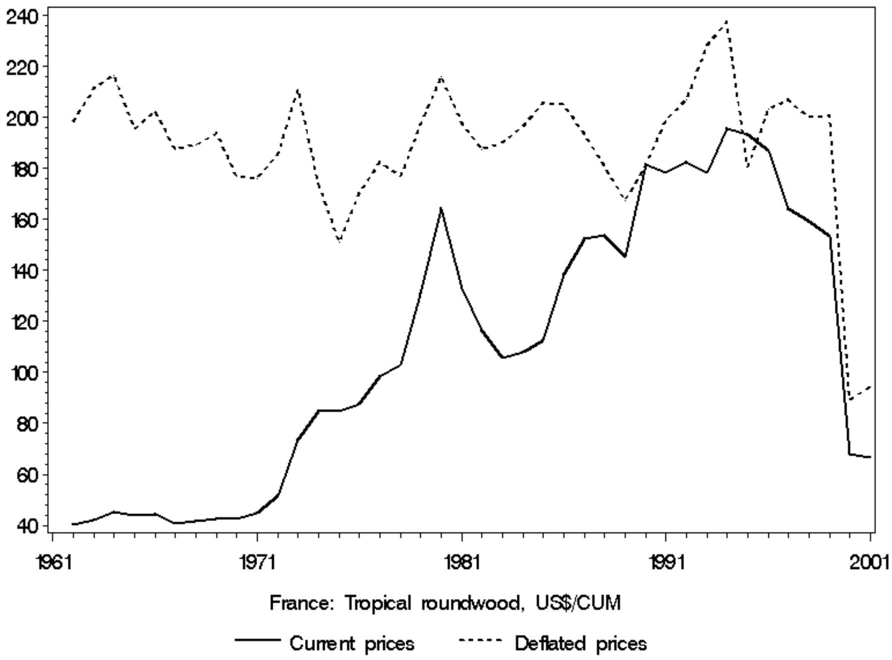

Figure A.25 Current and deflated prices of tropical roundwood.

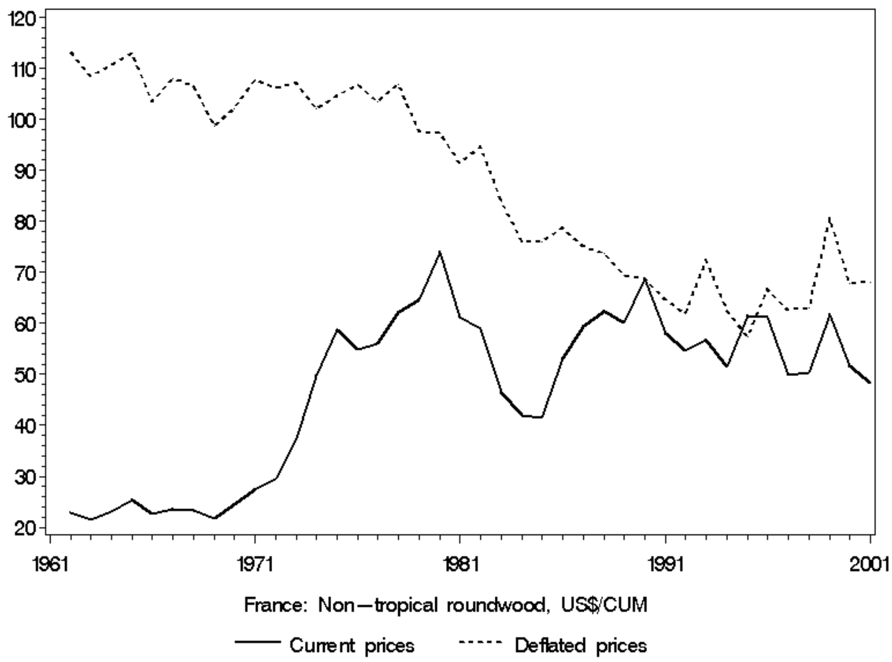

Figure A.26 Current and deflated prices of non-tropical roundwood.

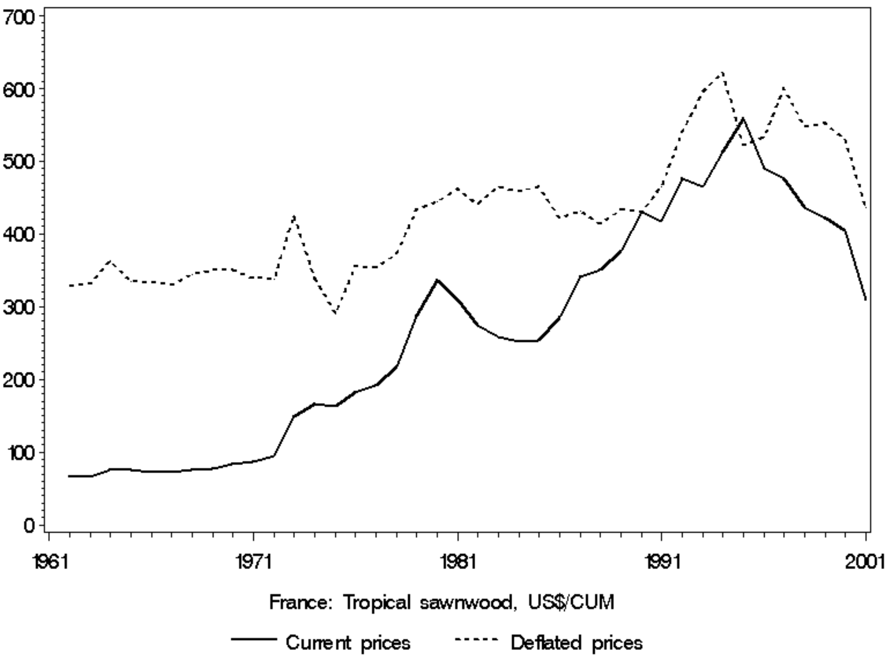

Figure A.27 Current and deflated prices of tropical sawnwood.

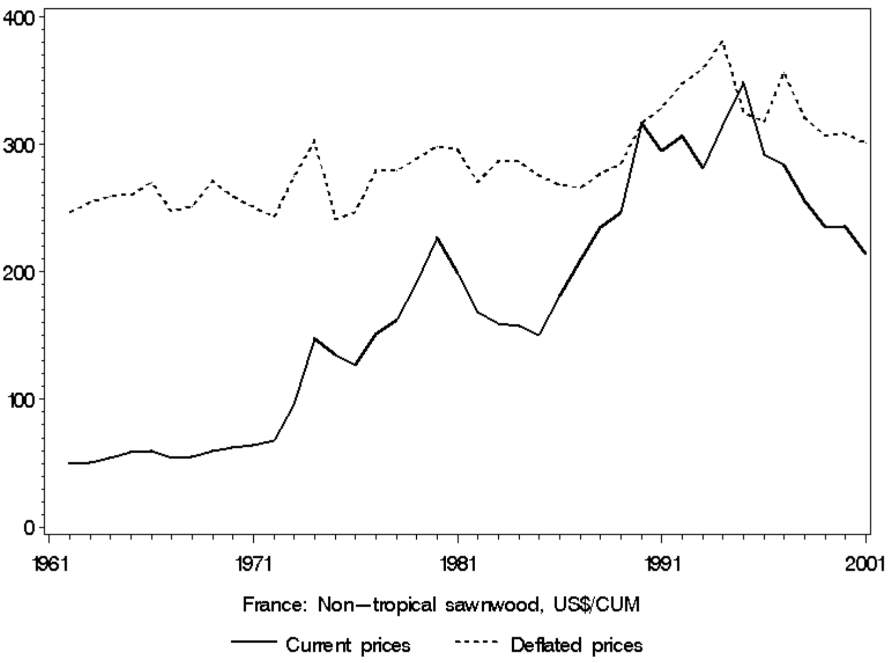

Figure A.28 Current and deflated prices of non-tropical sawnwood.

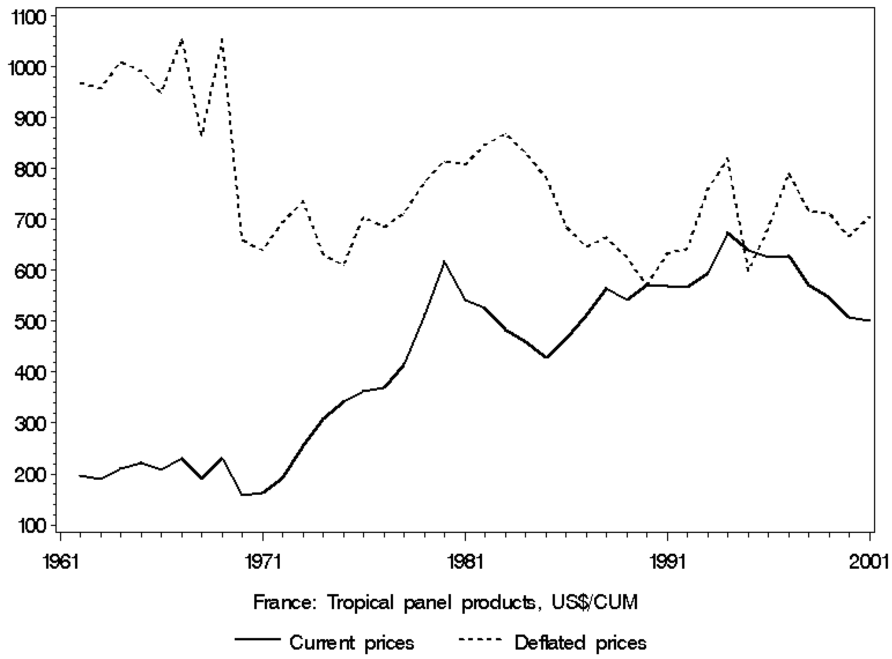

Figure A.29 Current and deflated prices of tropical panel products.

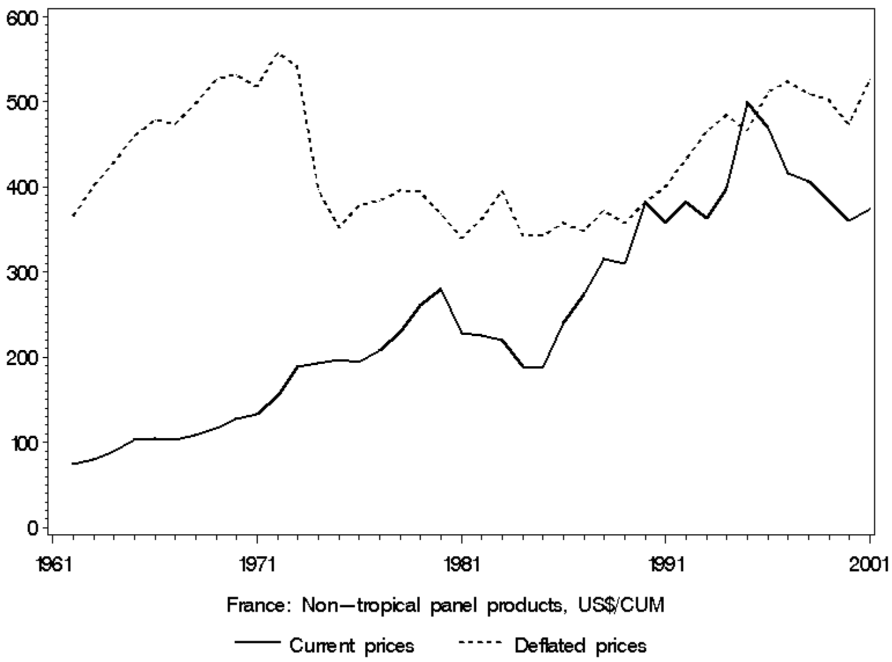

Figure A.30 Current and deflated prices of non-tropical panel products.

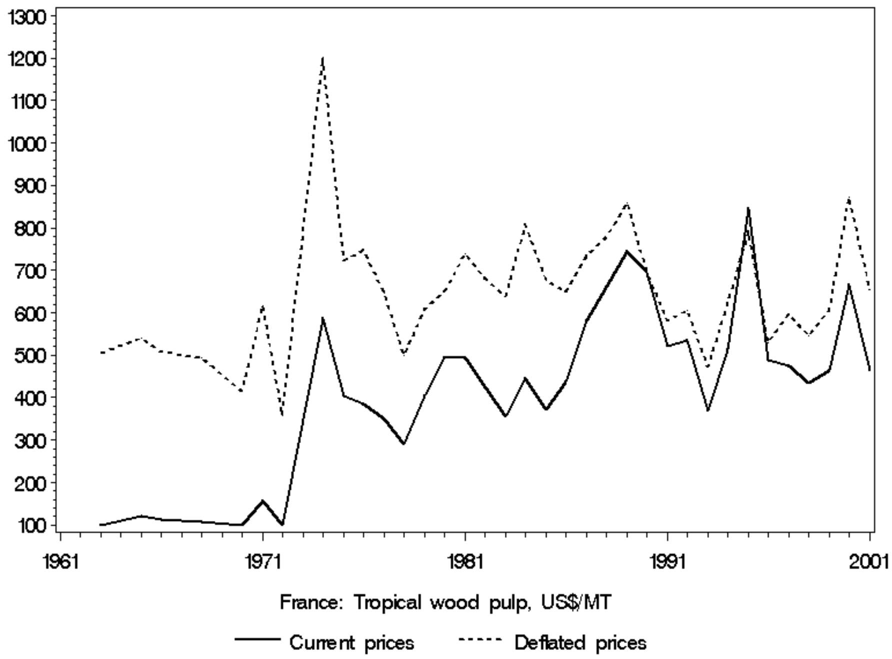

Figure A.31 Current and deflated prices of tropical wood pulp.

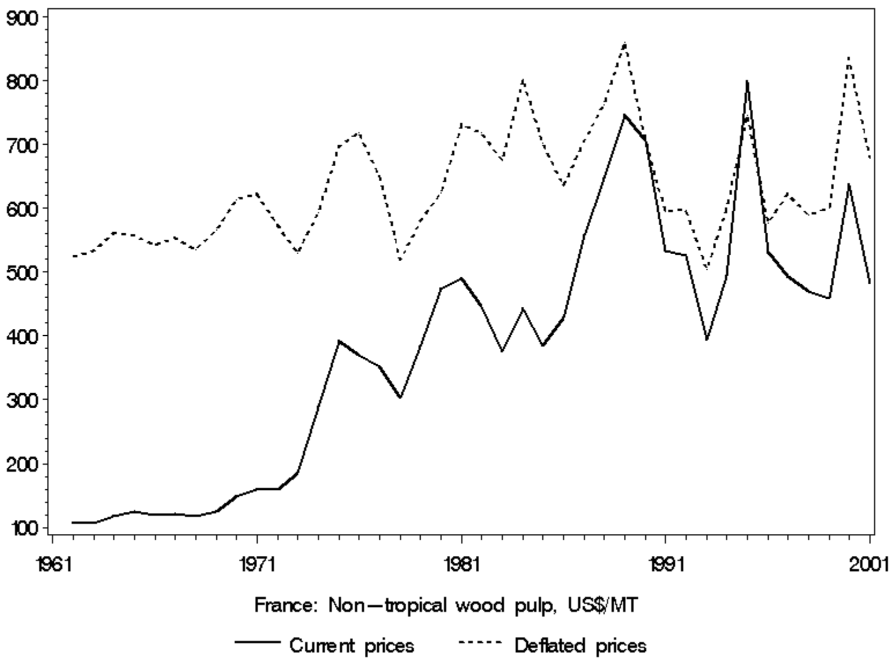

Figure A.32 Current and deflated prices of non-tropical wood pulp.

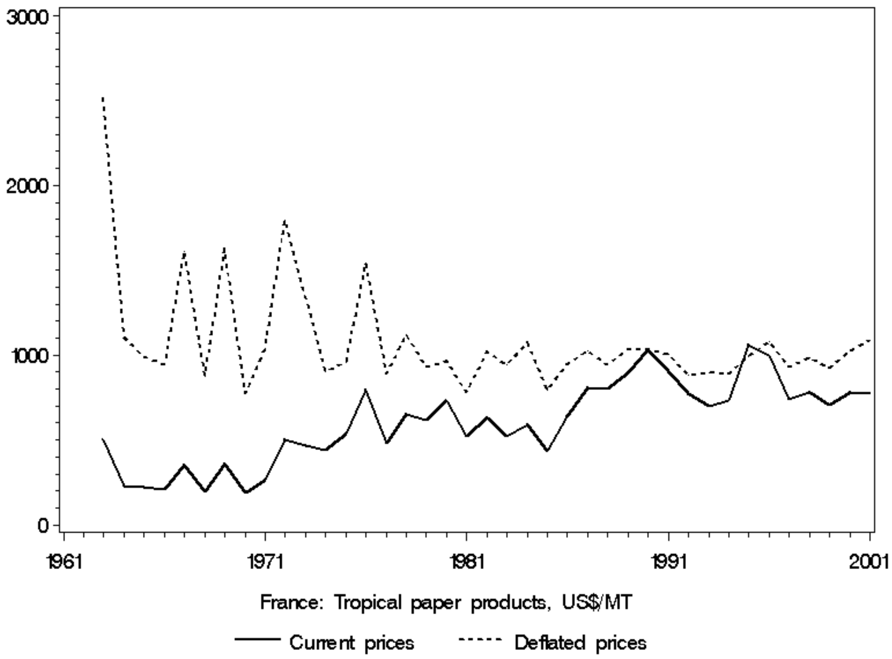

Figure A.33 Current and deflated prices of tropical paper products.

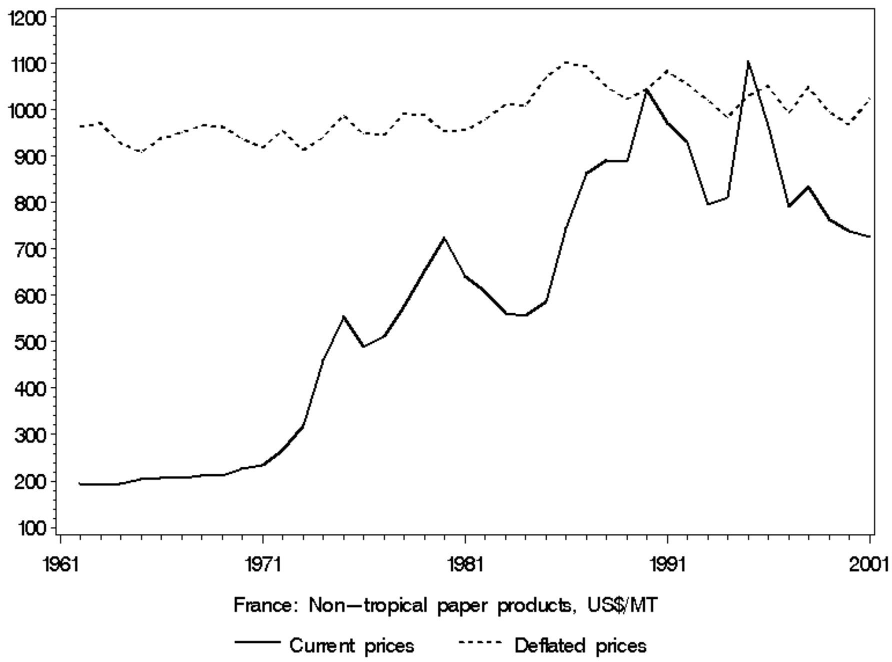

Figure A.34 Current and deflated prices of non-tropical paper products.

6.2.2 Germany

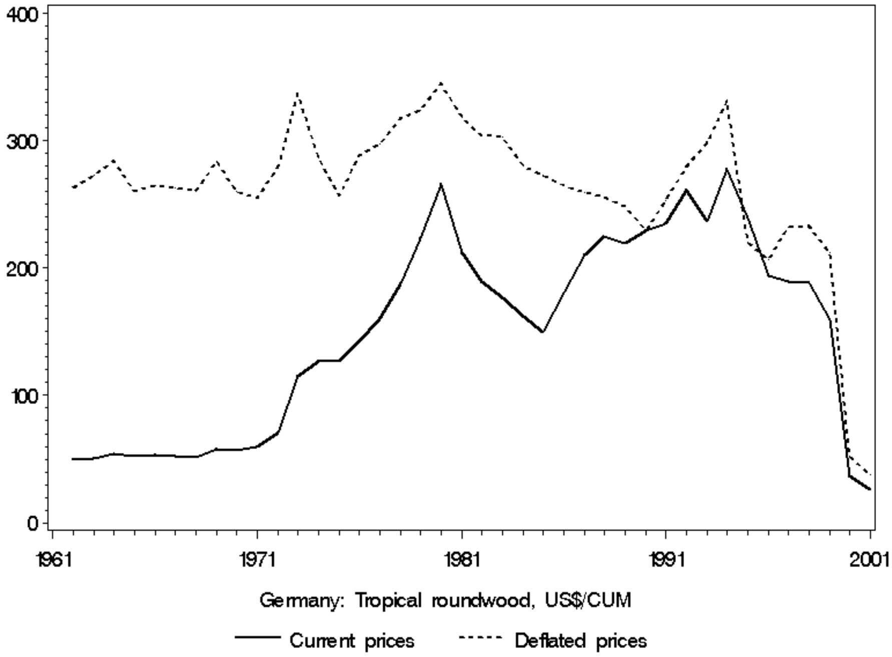

Figure A.35 Current and deflated prices of tropical roundwood.

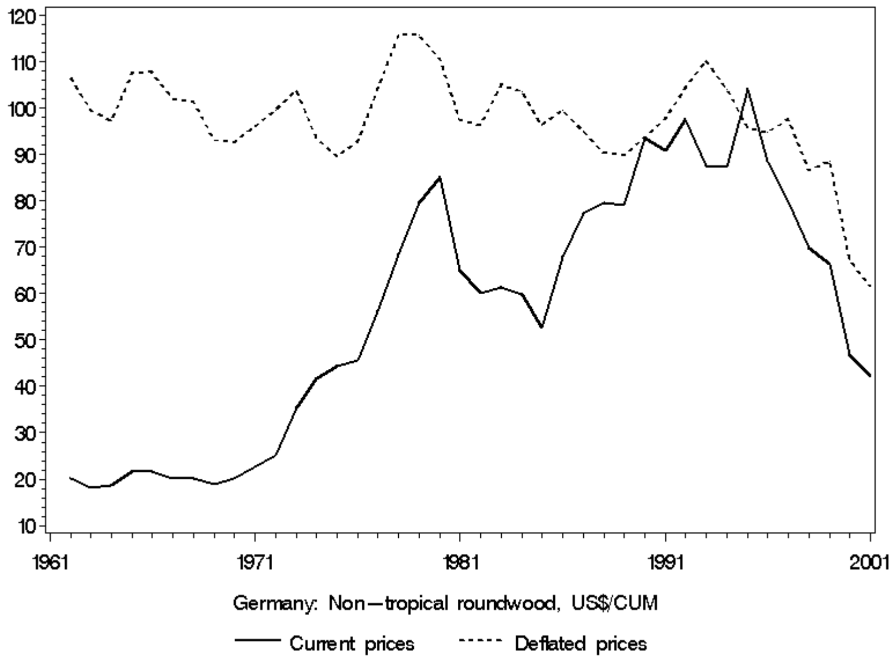

Figure A.36 Current and deflated prices of non-tropical roundwood.

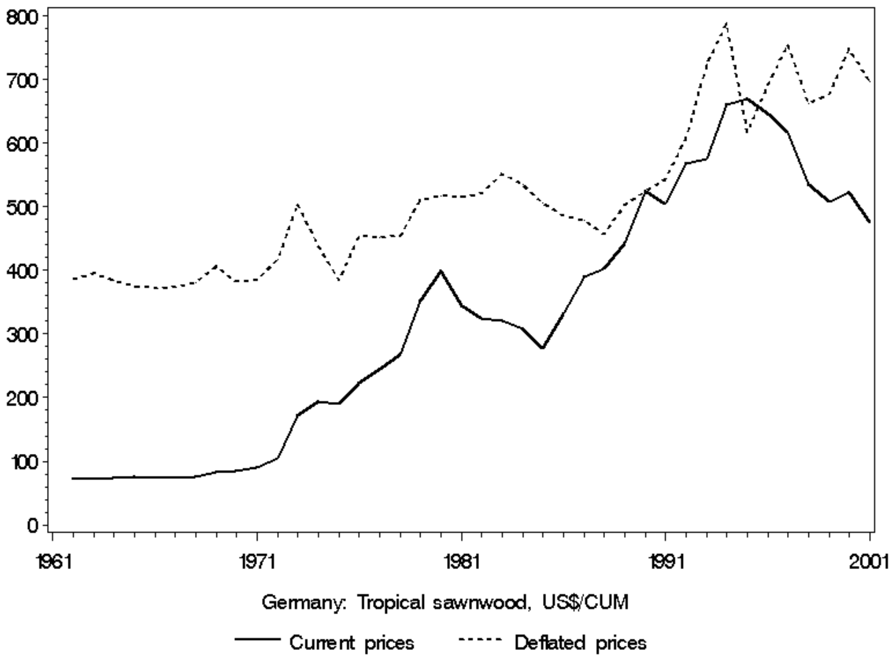

Figure A.37 Current and deflated prices of tropical sawnwood.

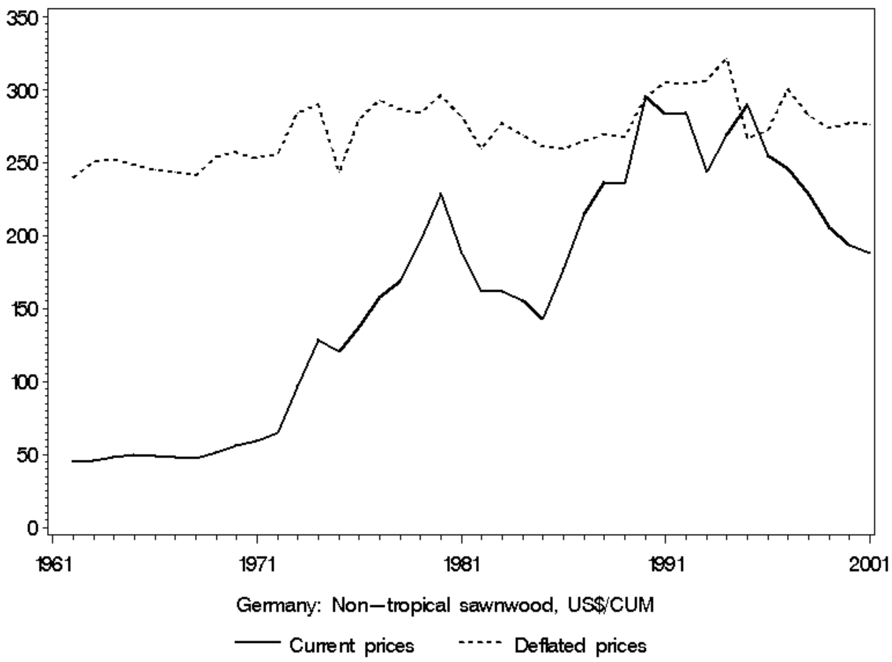

Figure A.38 Current and deflated prices of non-tropical sawnwood.

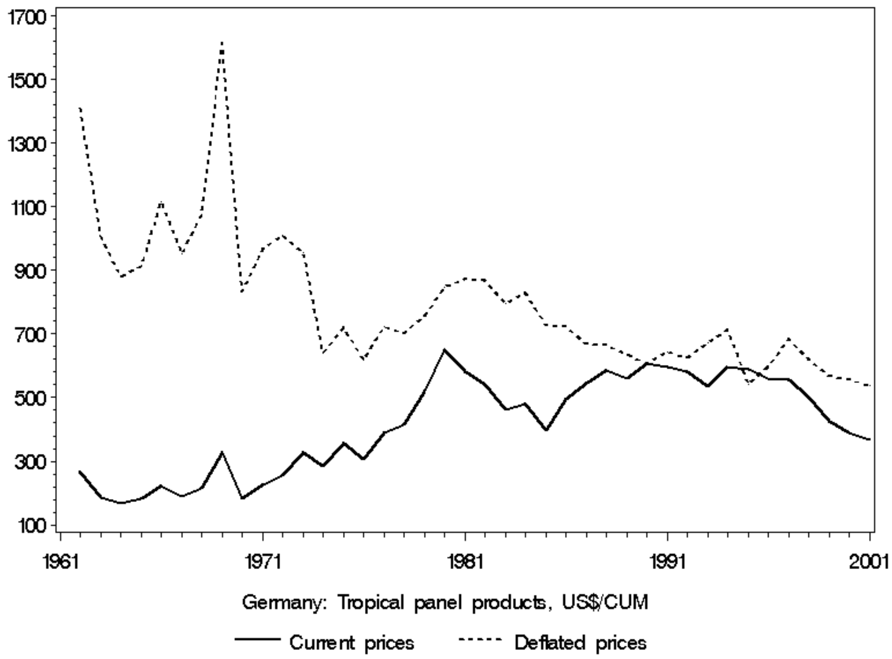

Figure A.39 Current and deflated prices of tropical panel products.

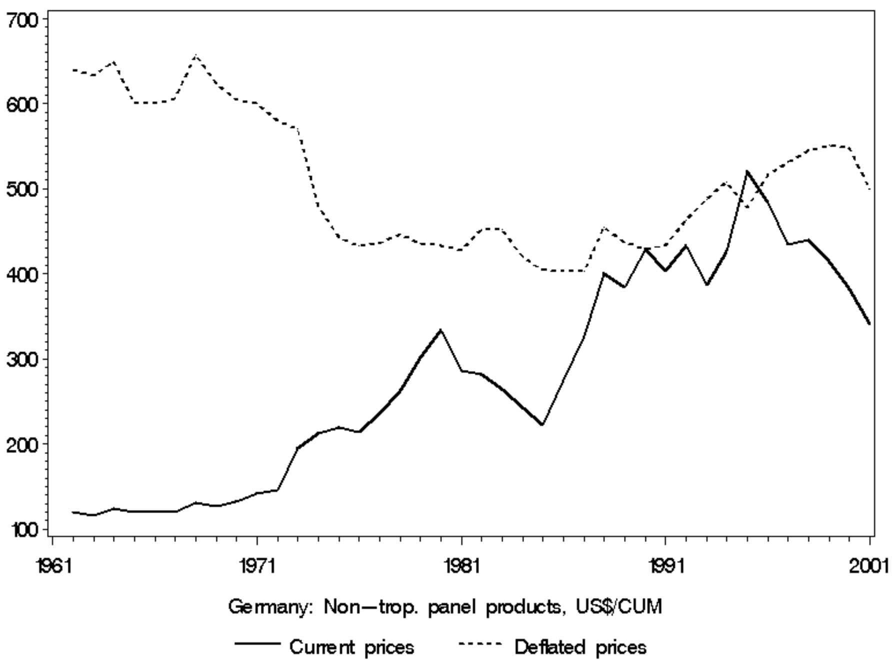

Figure A.40 Current and deflated prices of non-tropical panel products.

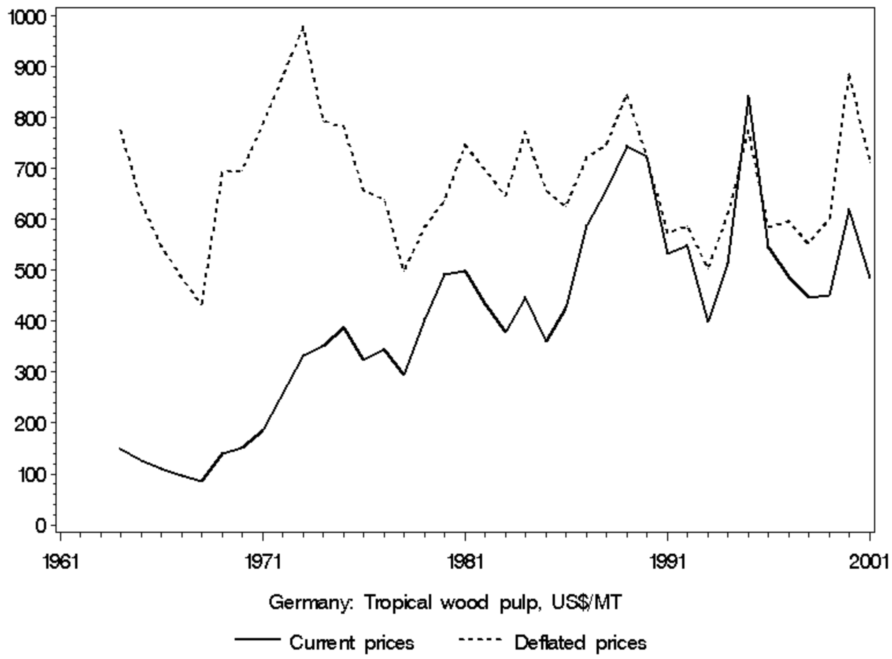

Figure A.41 Current and deflated prices of tropical wood pulp.

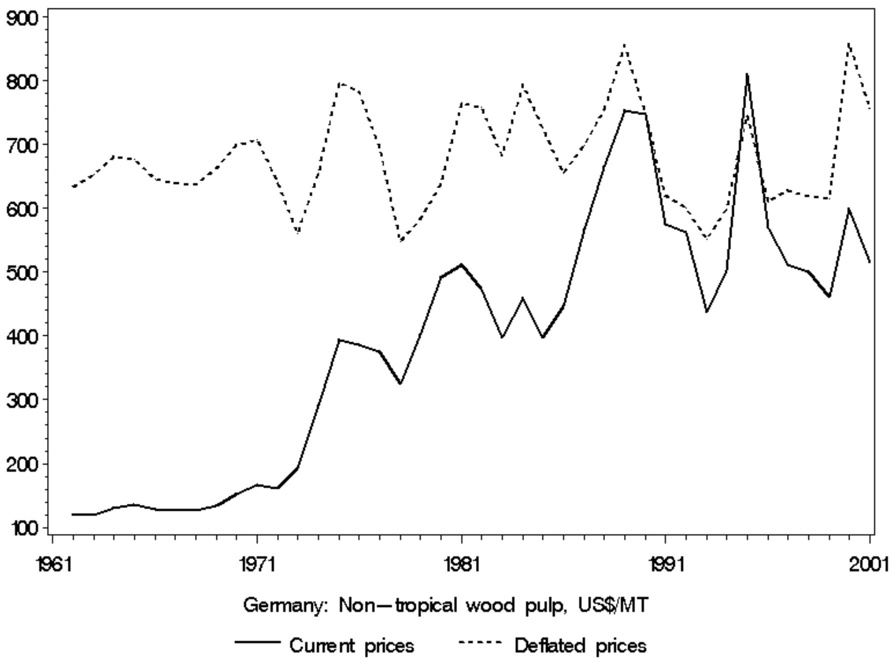

Figure A.42 Current and deflated prices of non-tropical wood pulp.

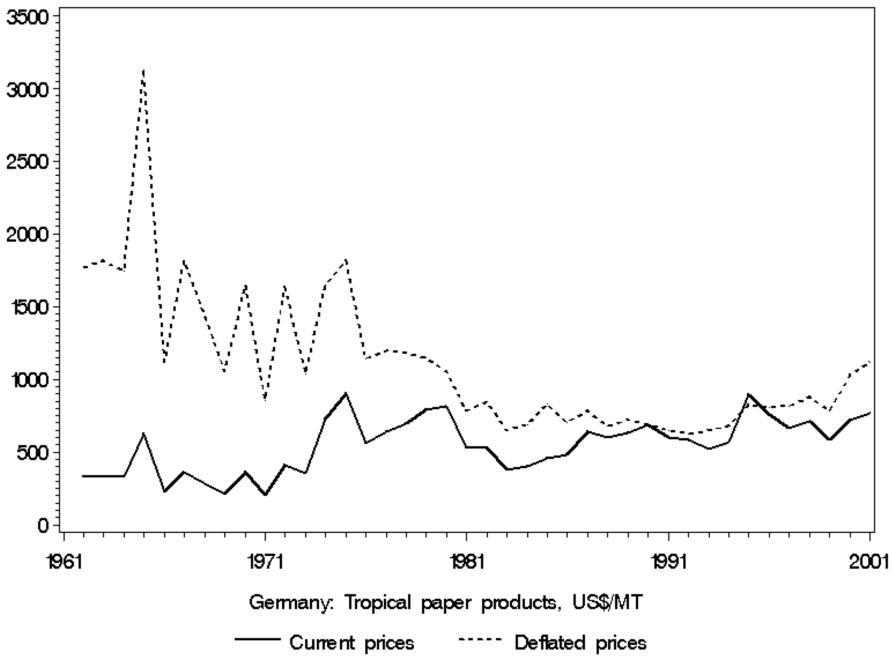

Figure A.43 Current and deflated prices of tropical paper products.

Figure A.44 Current and deflated prices of non-tropical paper products.

6.2.3 Italy

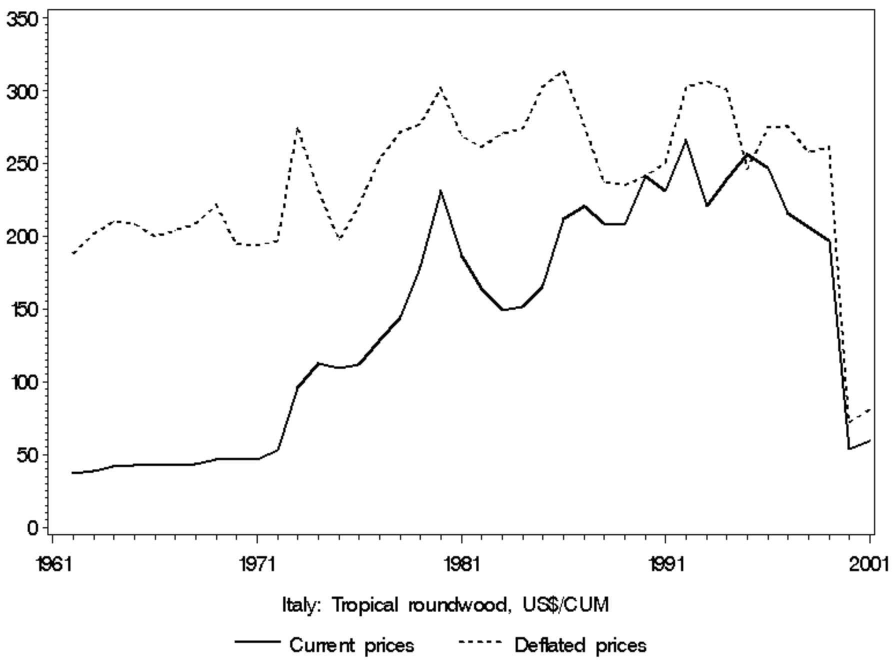

Figure A.45 Current and deflated prices of tropical roundwood.

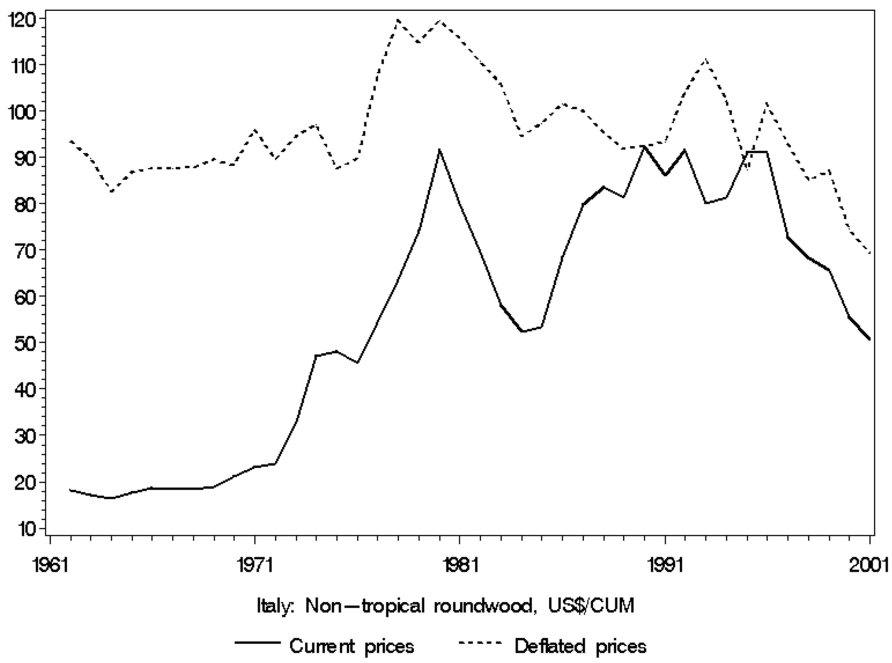

Figure A.46 Current and deflated prices of non-tropical roundwood.

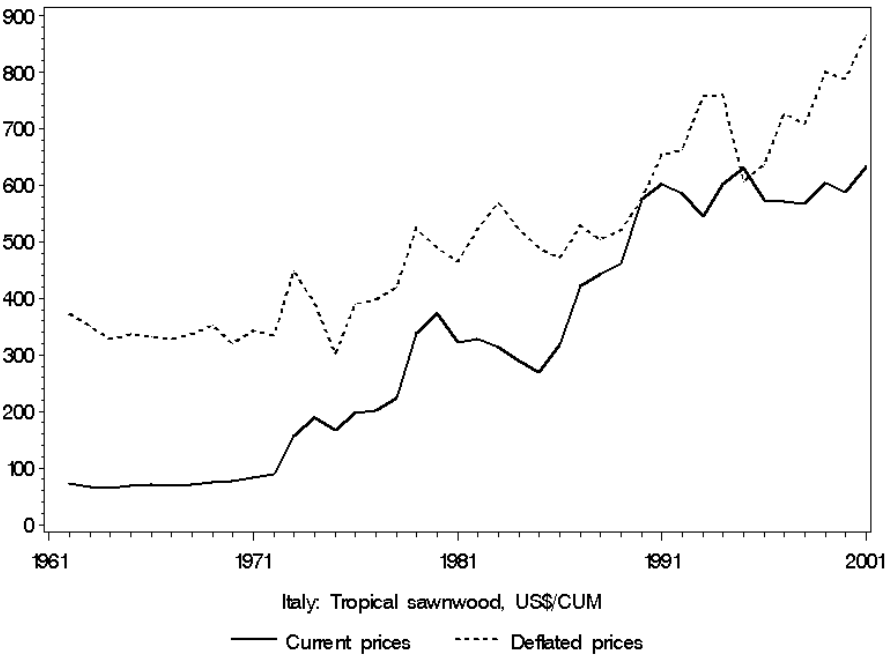

Figure A.47 Current and deflated prices of tropical sawnwood.

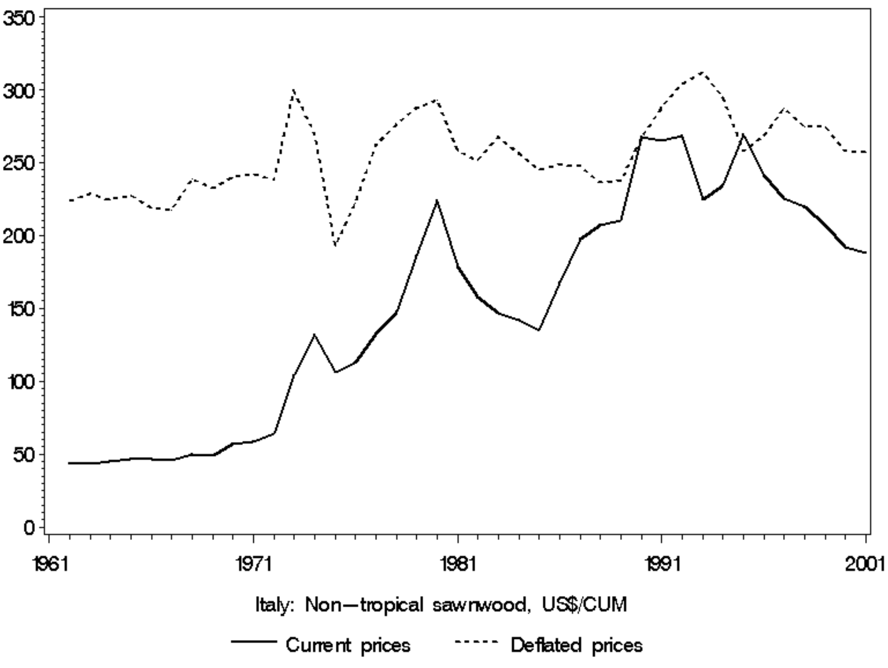

Figure A.48 Current and deflated prices of non-tropical sawnwood.

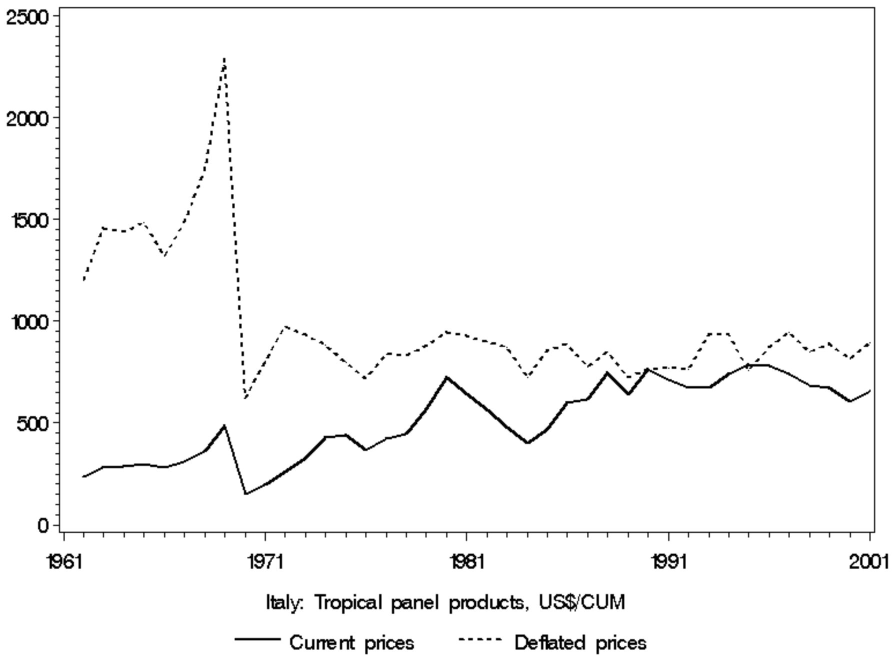

Figure A.49 Current and deflated prices of tropical panel products.

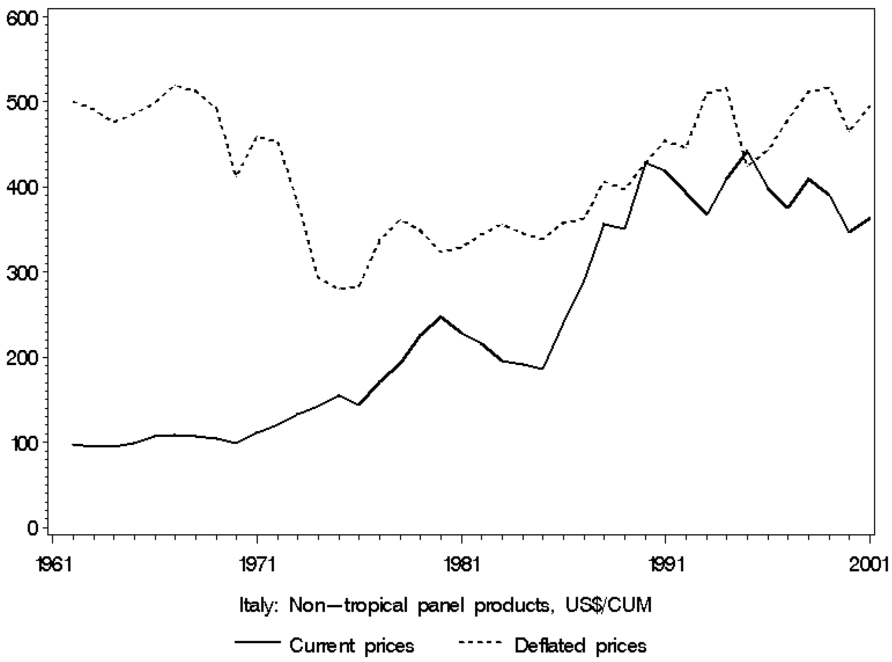

Figure A.50 Current and deflated prices of non-tropical panel products.

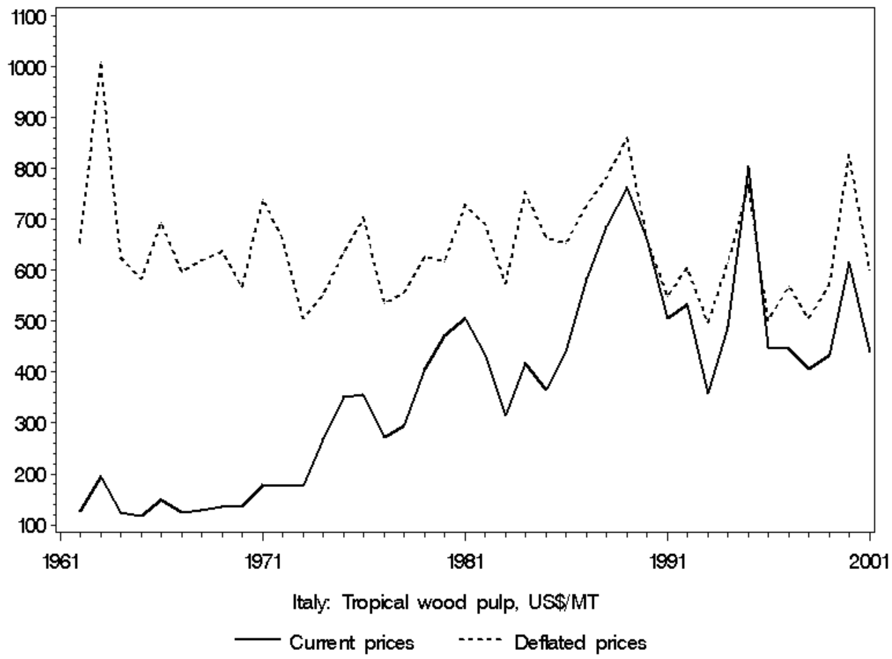

Figure A.51 Current and deflated prices of tropical wood pulp.

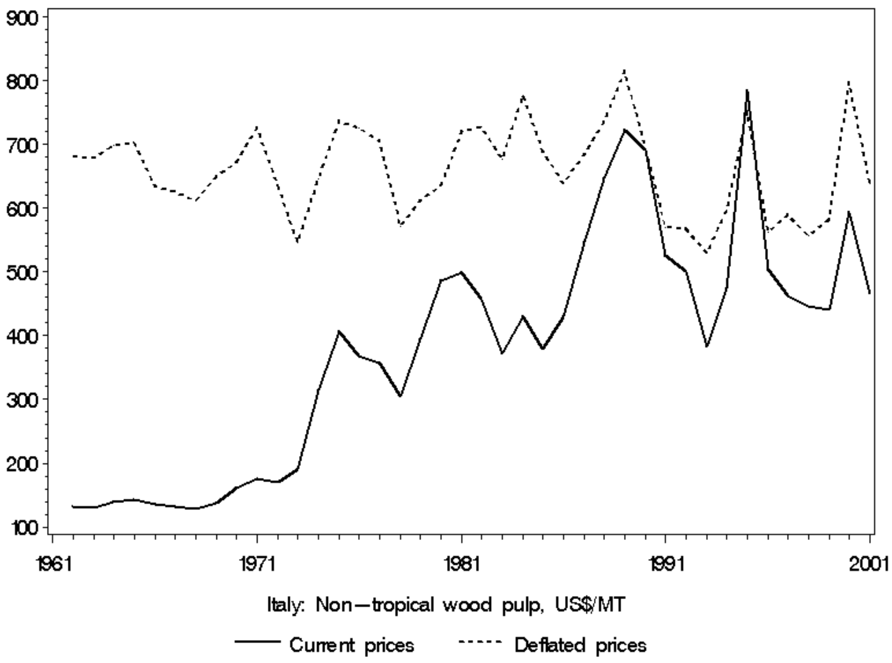

Figure A.52 Current and deflated prices of non-tropical wood pulp.

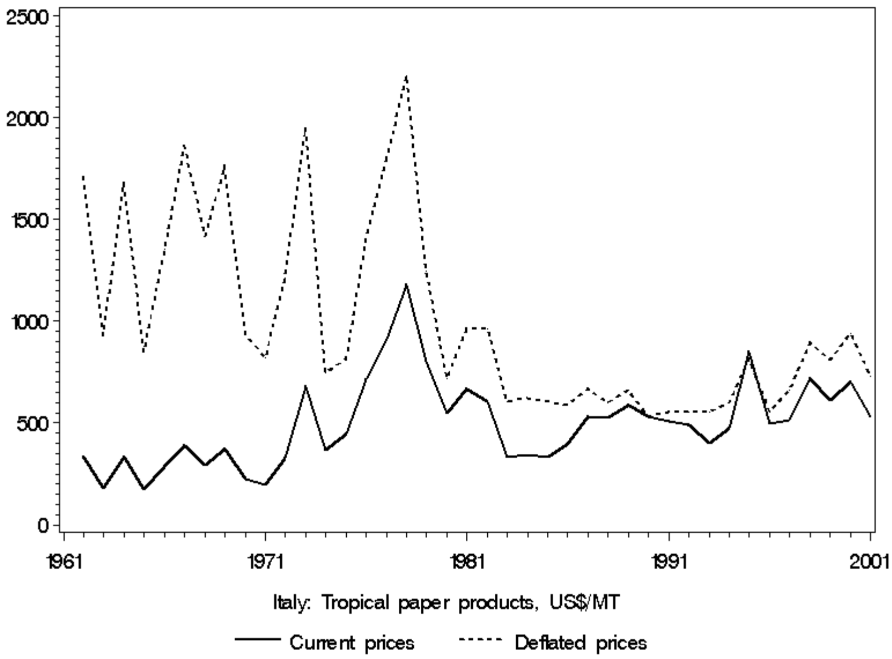

Figure A.53 Current and deflated prices of tropical paper products.

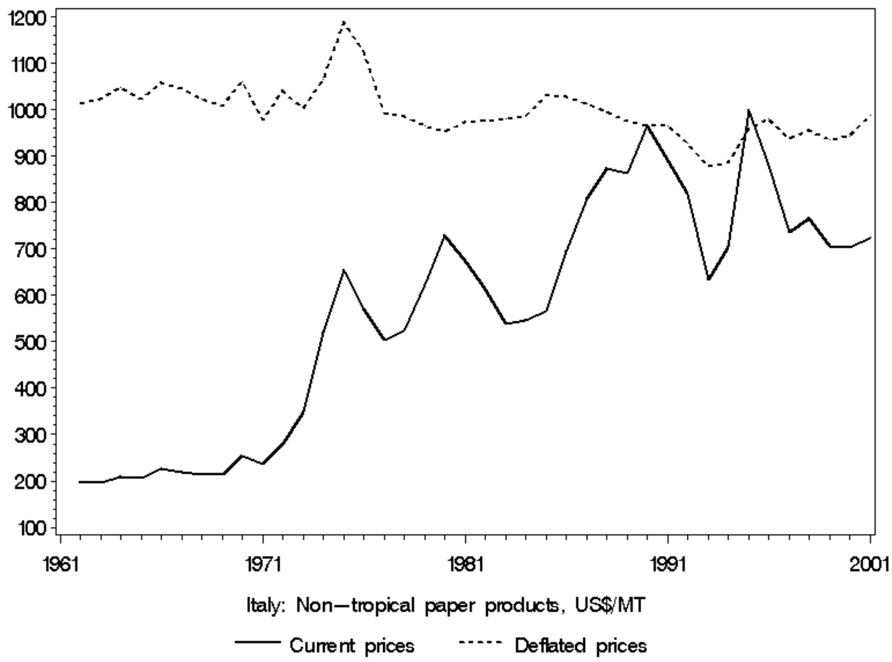

Figure A.54 Current and deflated prices of non-tropical paper products.

6.2.4 Japan

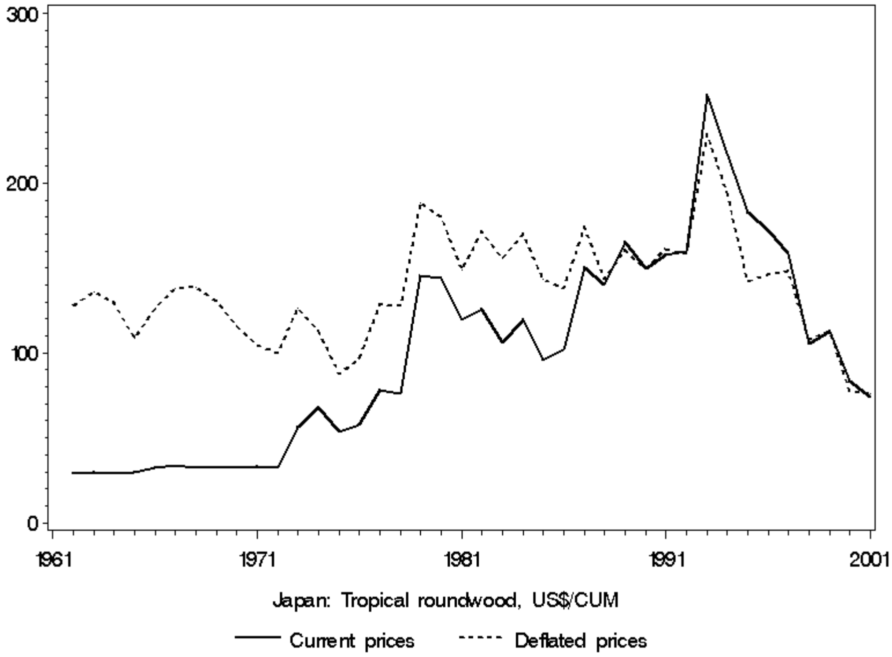

Figure A.55 Current and deflated prices of tropical roundwood.

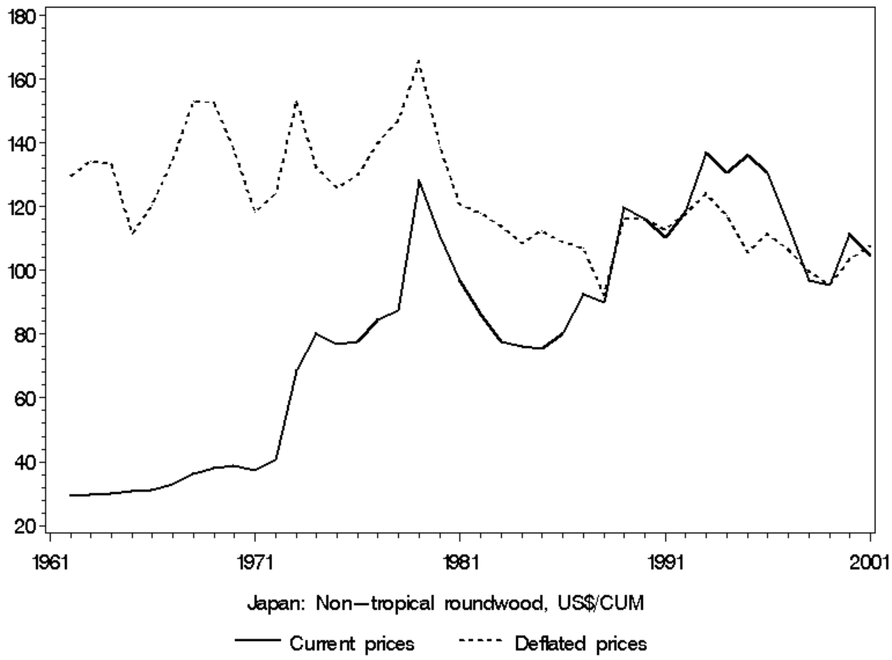

Figure A.56 Current and deflated prices of non-tropical roundwood.

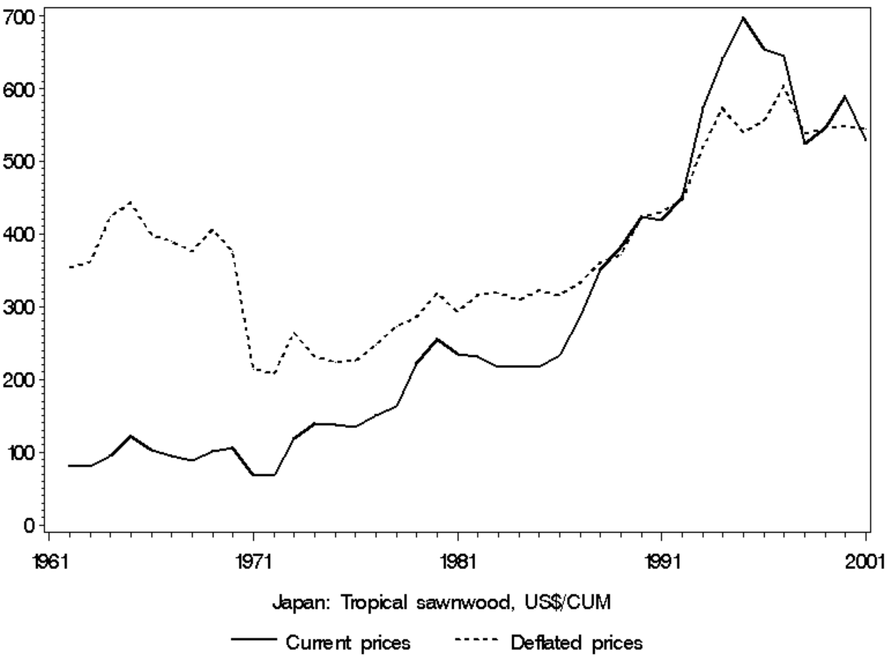

Figure A.57 Current and deflated prices of tropical sawnwood.

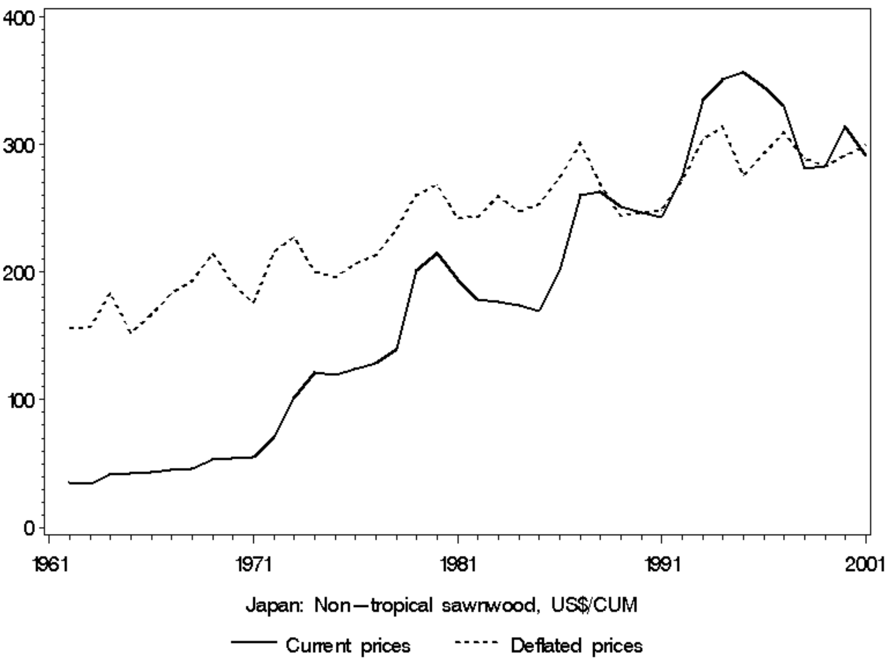

Figure A.58 Current and deflated prices of non-tropical sawnwood.

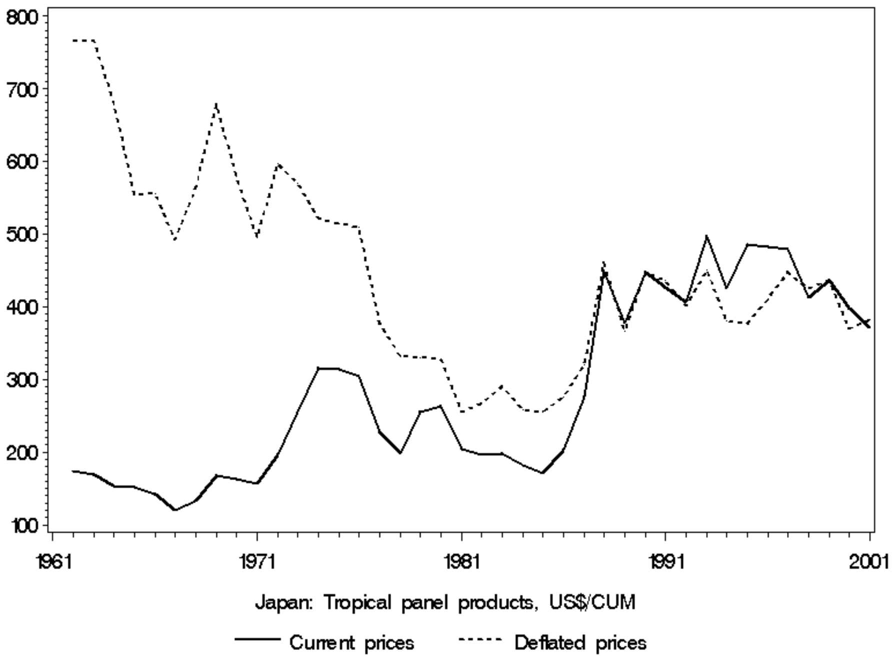

Figure A.59 Current and deflated prices of tropical panel products.

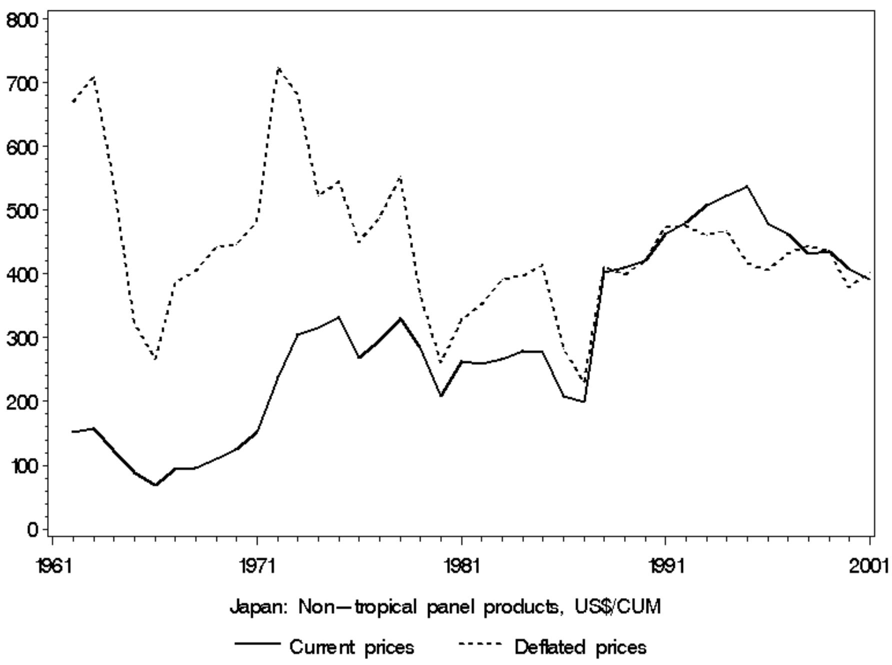

Figure A.60 Current and deflated prices of non-tropical panel products.

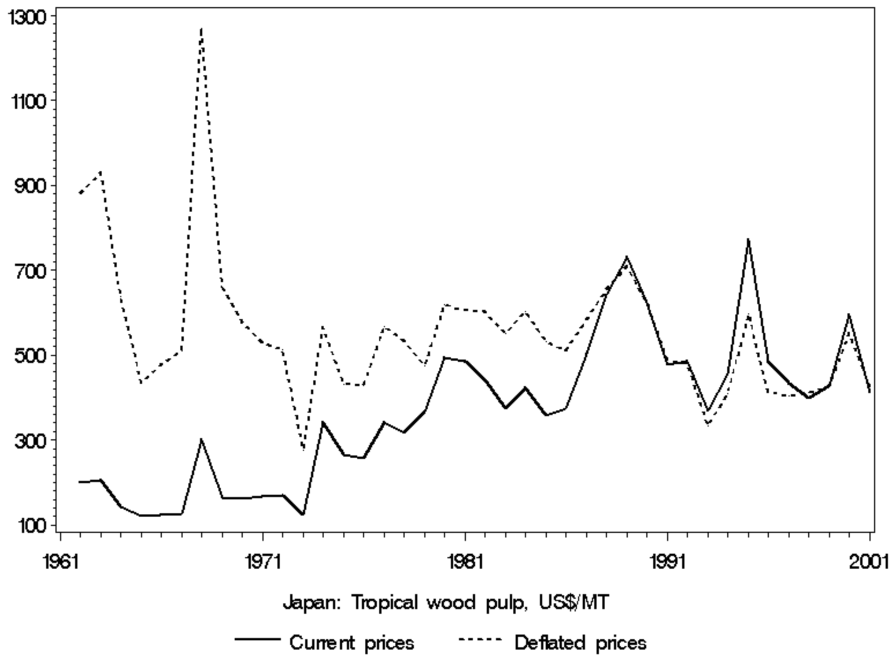

Figure A.61 Current and deflated prices of tropical wood pulp.

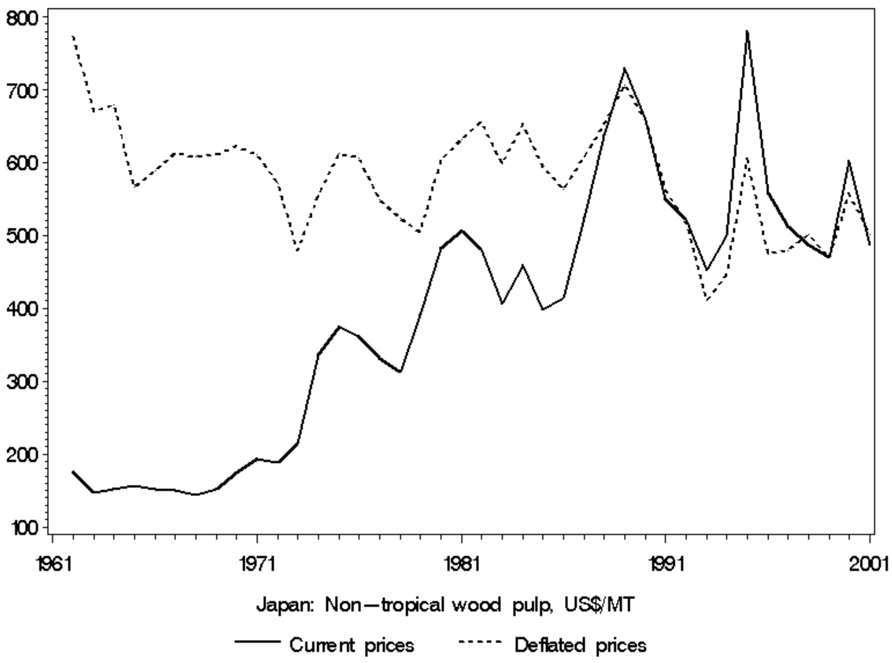

Figure A.62 Current and deflated prices of non-tropical wood pulp.

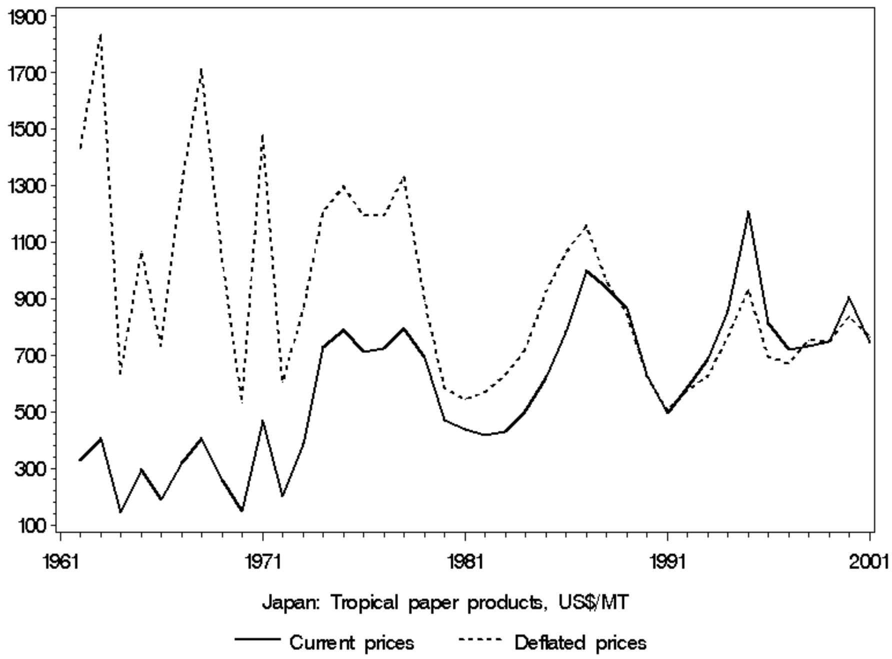

Figure A.63 Current and deflated prices of tropical paper products.

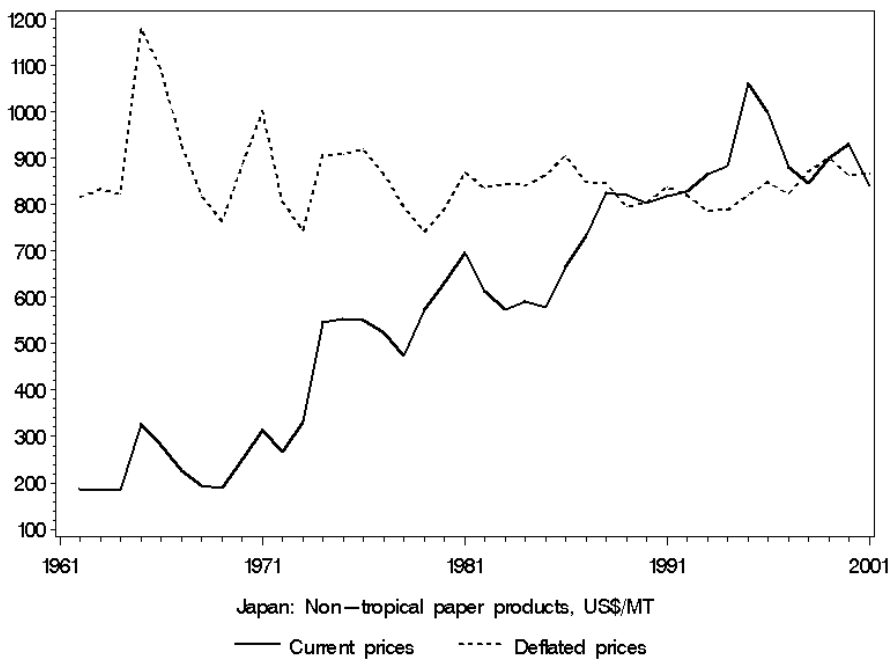

Figure A.64 Current and deflated prices of non-tropical paper products.

6.2.5 United Kingdom

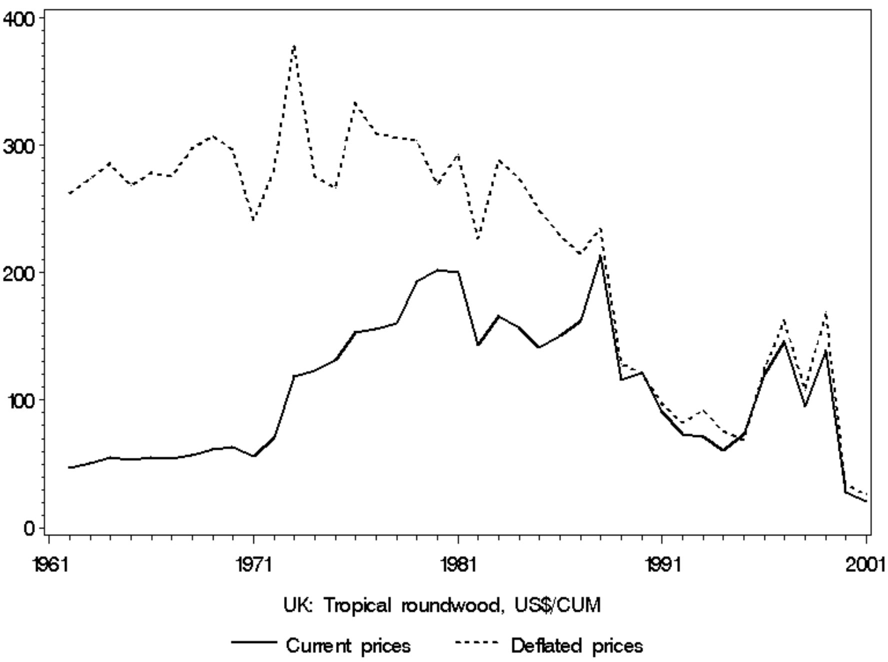

Figure A.65 Current and deflated prices of tropical roundwood.

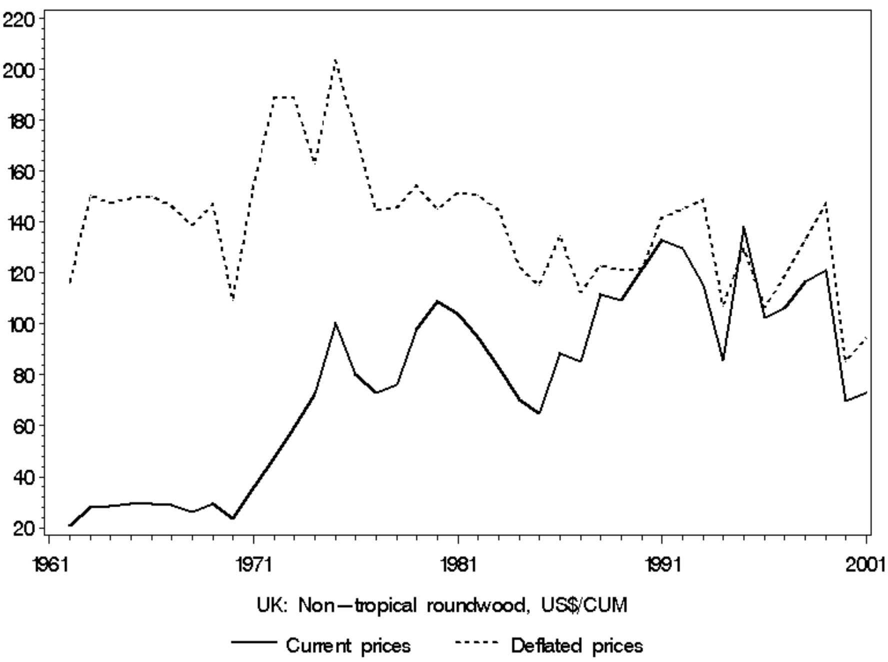

Figure A.66 Current and deflated prices of non-tropical roundwood.

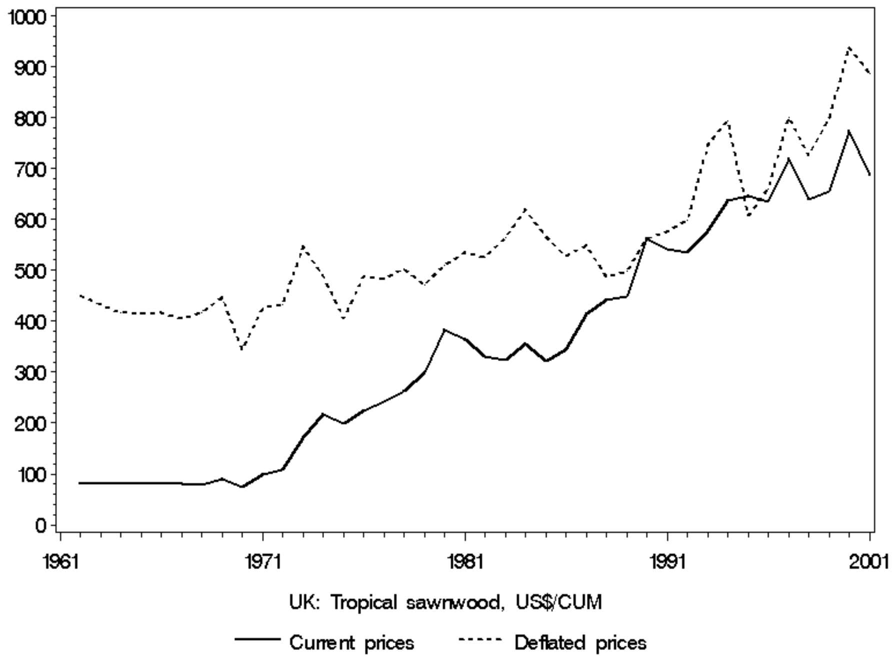

Figure A.67 Current and deflated prices of tropical sawnwood.

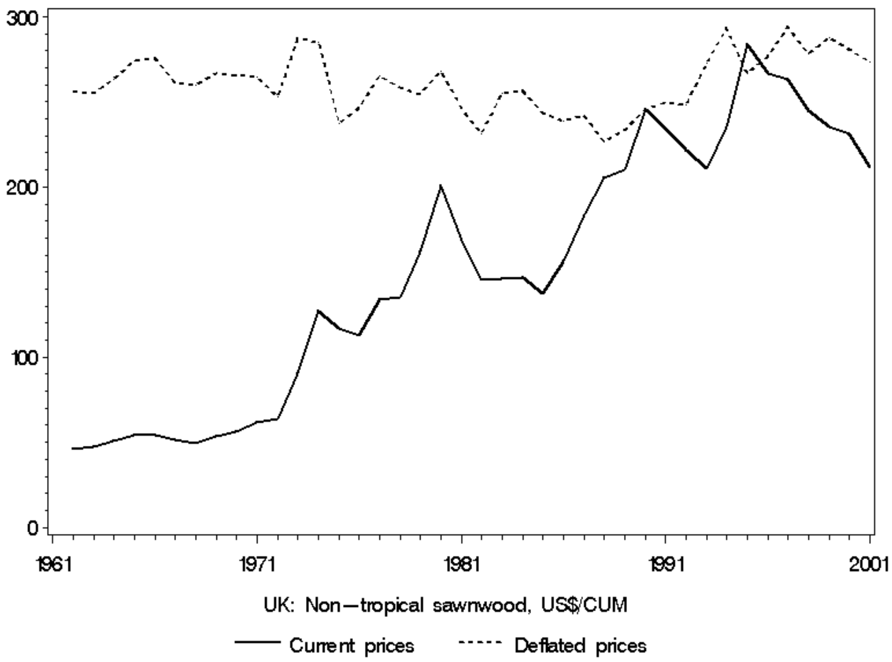

Figure A.68 Current and deflated prices of non-tropical roundwood.

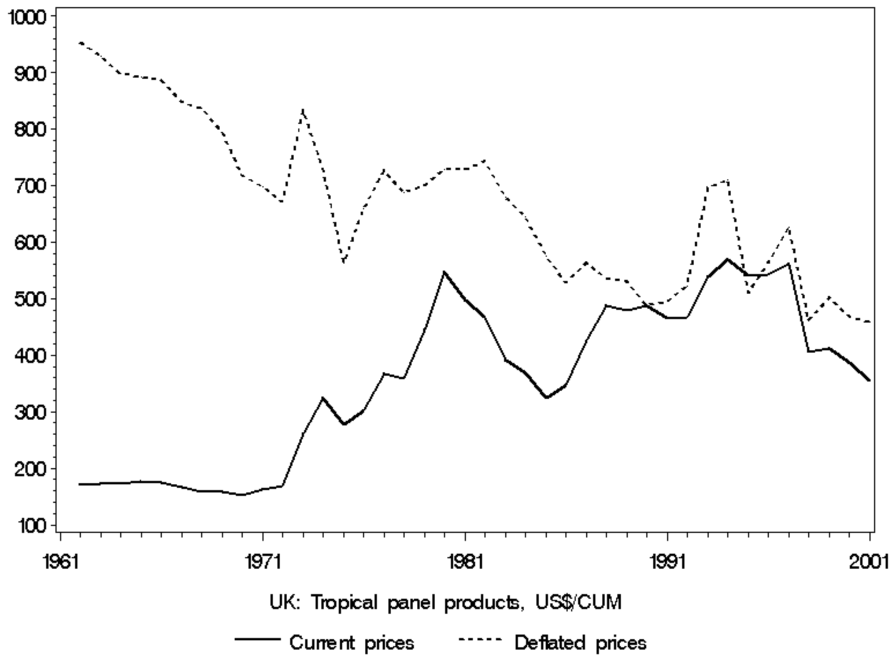

Figure A.69 Current and deflated prices of tropical panel products.

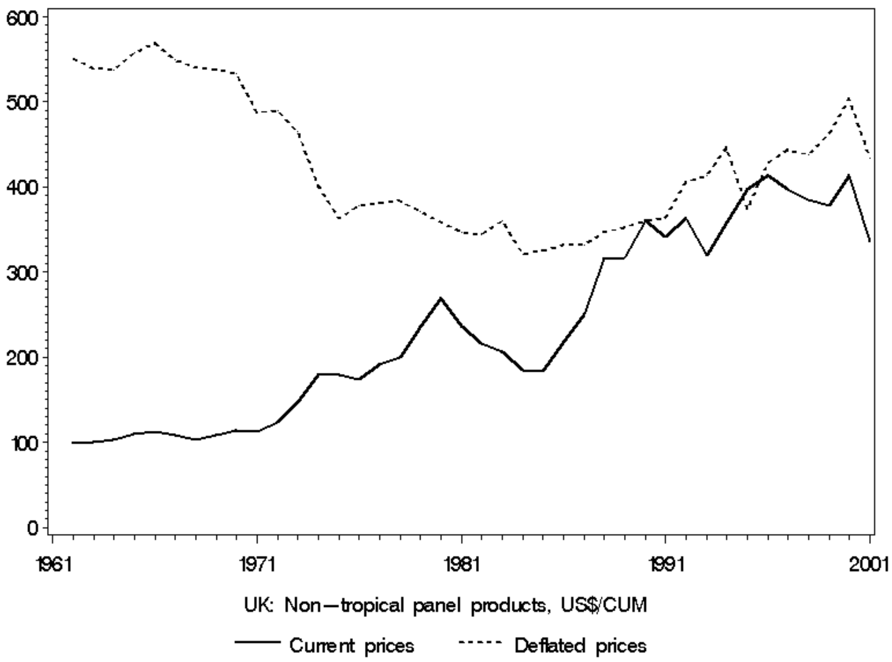

Figure A.70 Current and deflated prices of non-tropical panel products.

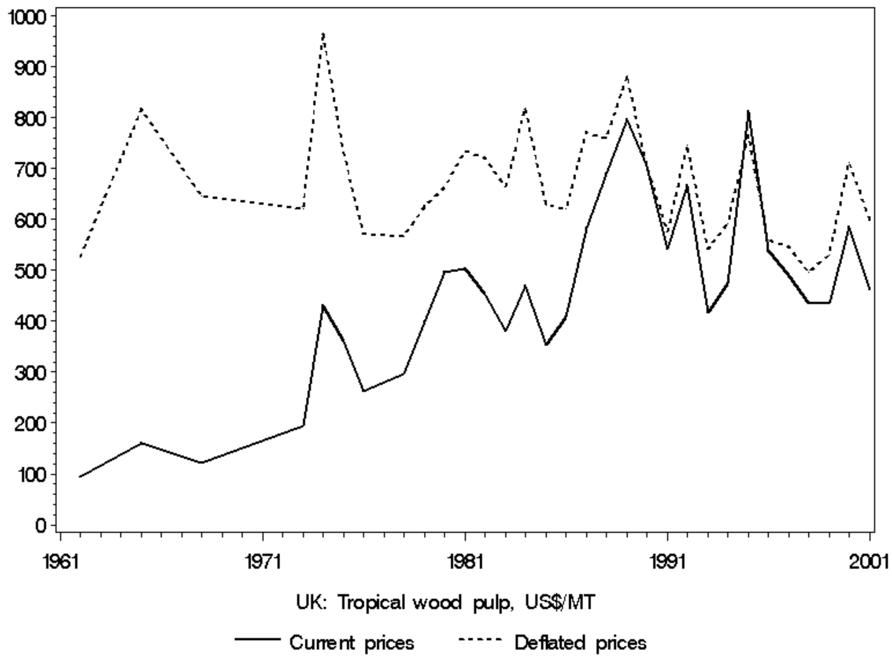

Figure A.71 Current and deflated prices of tropical wood pulp.

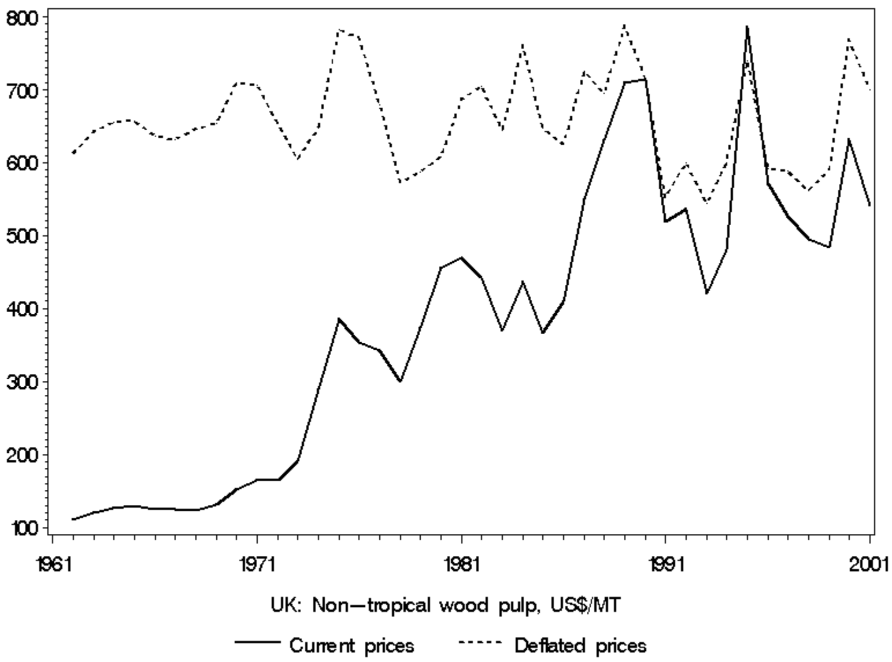

Figure A.72 Current and deflated prices of non-tropical wood pulp.

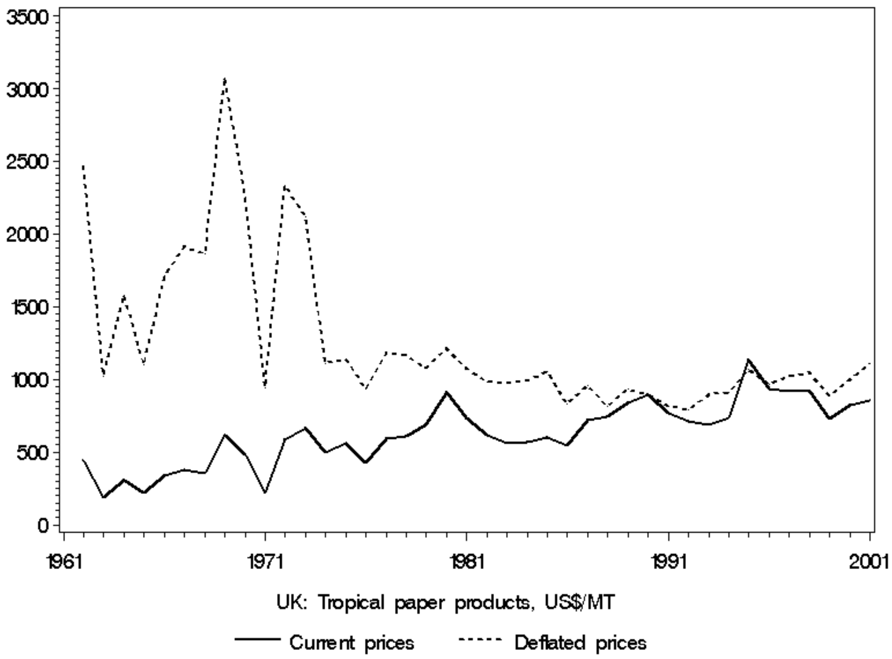

Figure A.73 Current and deflated prices of tropical paper products.

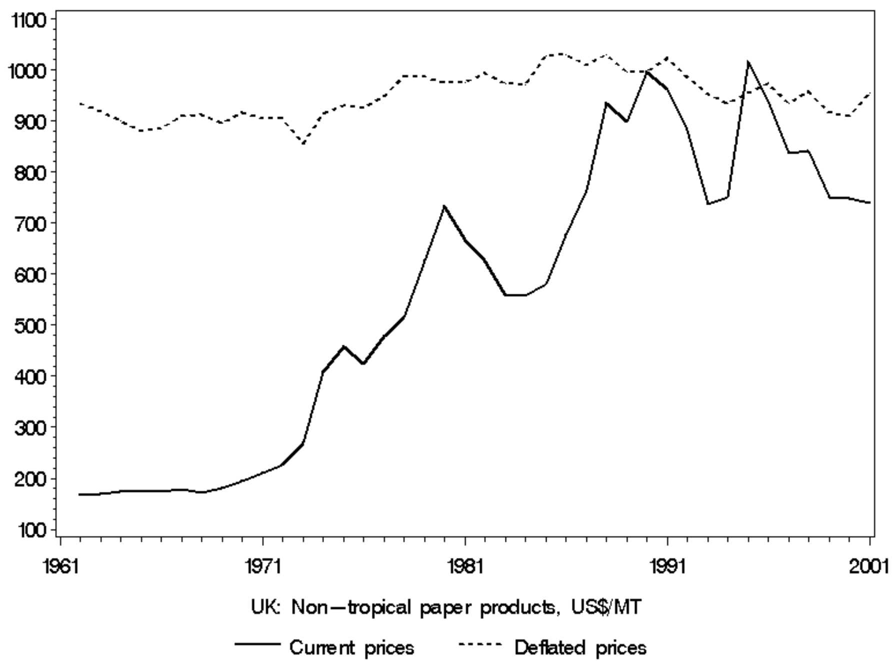

Figure A.74 Current and deflated prices of non-tropical paper products.

6.2.6 United States

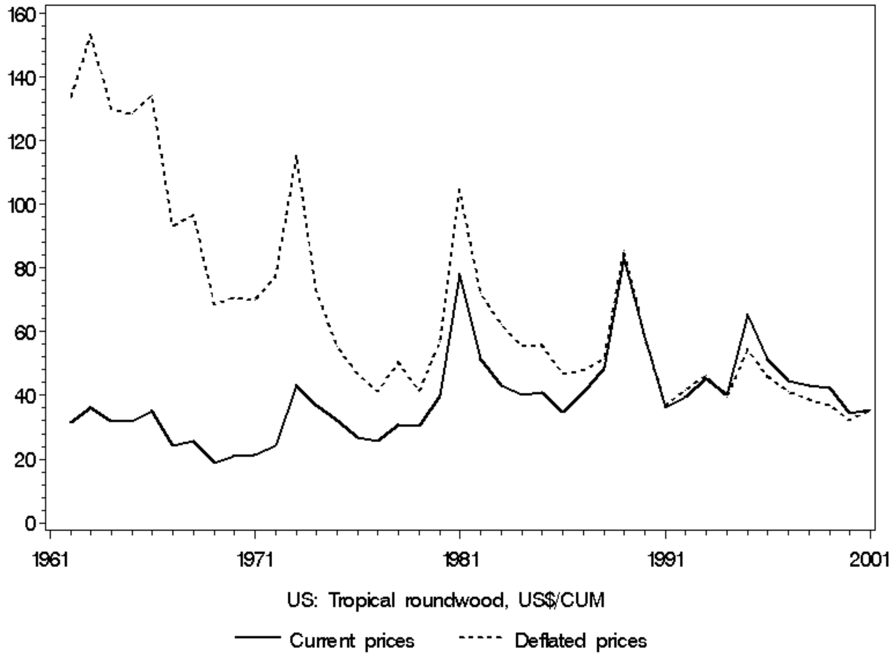

Figure A.75 Current and deflated prices of tropical hardwood.

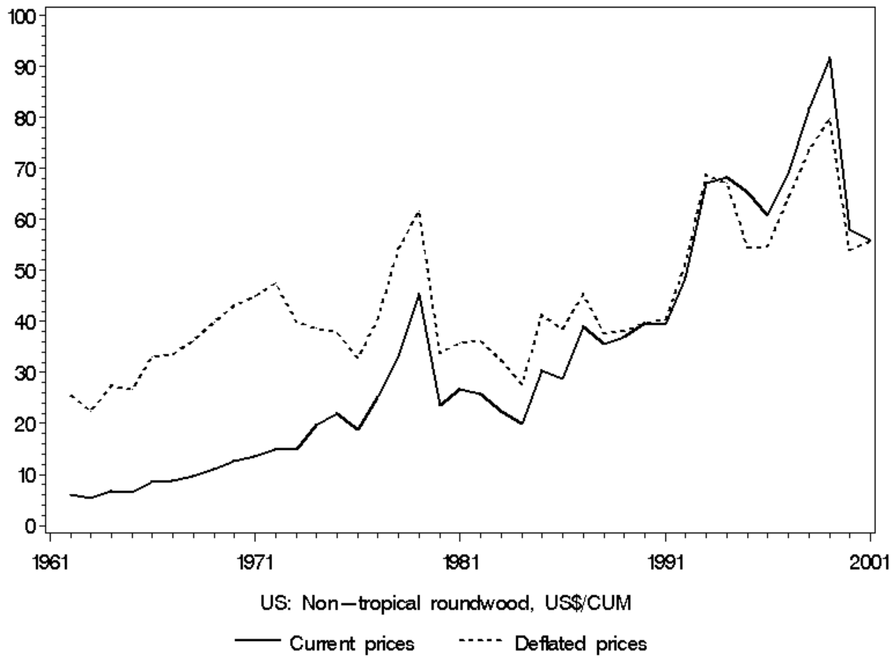

Figure A.76 Current and deflated prices of non-tropical roundwood.

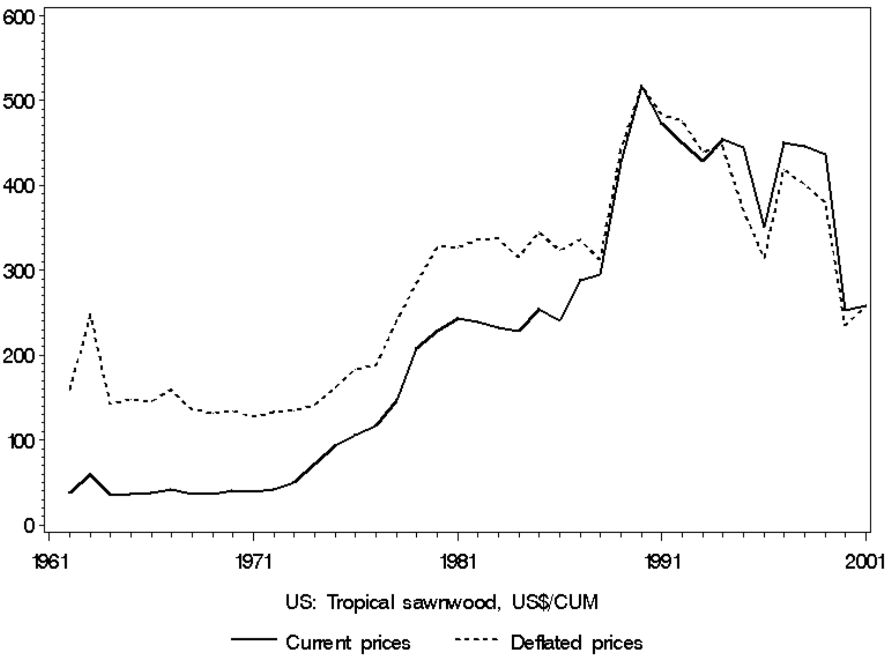

Figure A.77 Current and deflated prices of tropical sawnwood.

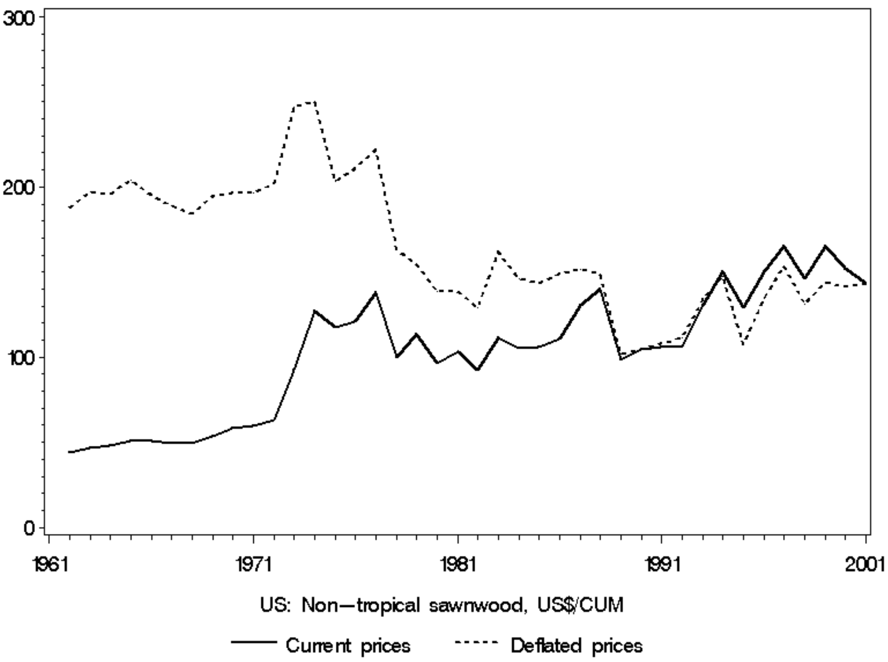

Figure A.78 Current and deflated prices of non-tropical sawnwood.

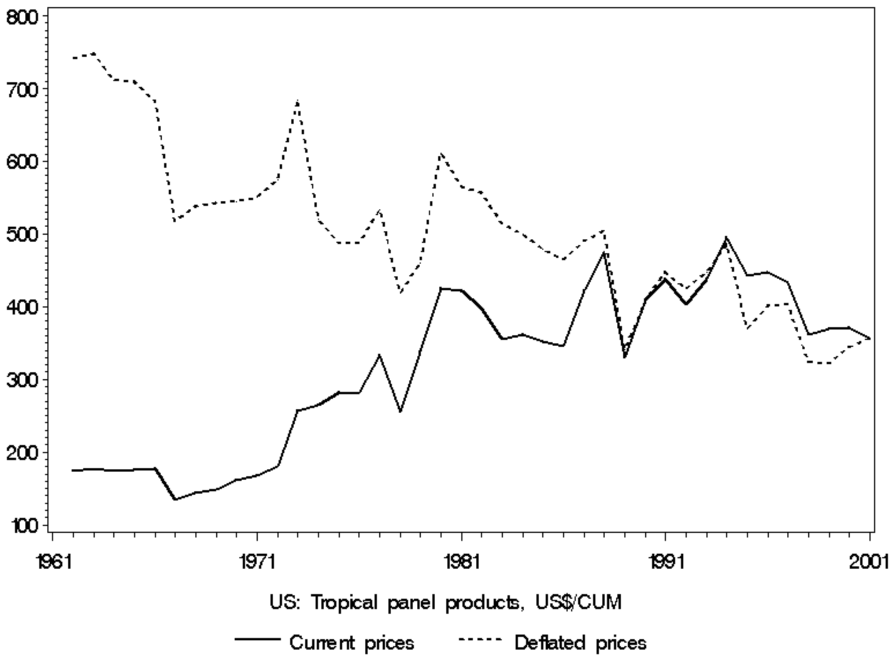

Figure A.79 Current and deflated prices of tropical panel products.

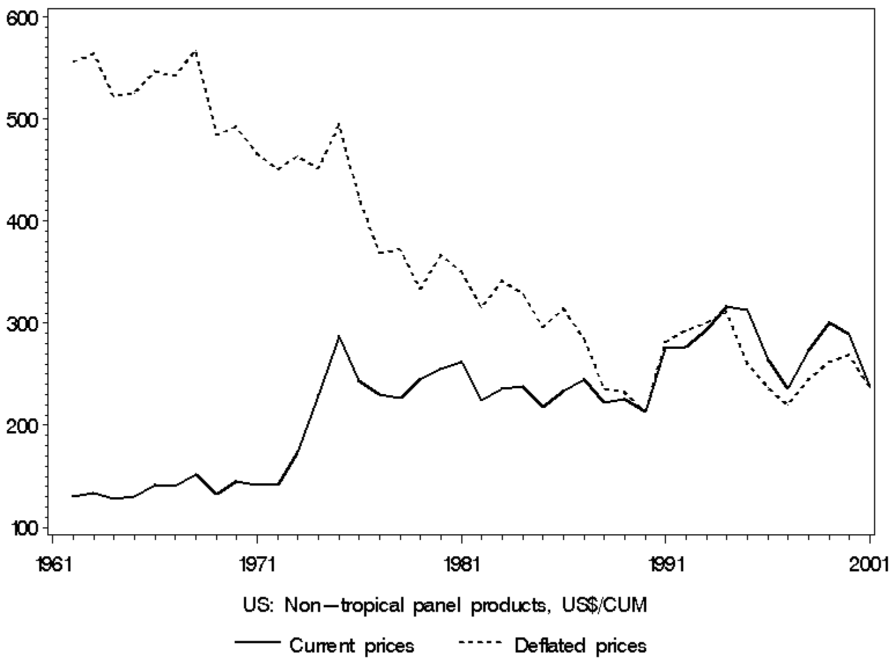

Figure A.80 Current and deflated prices of non-tropical panel products.

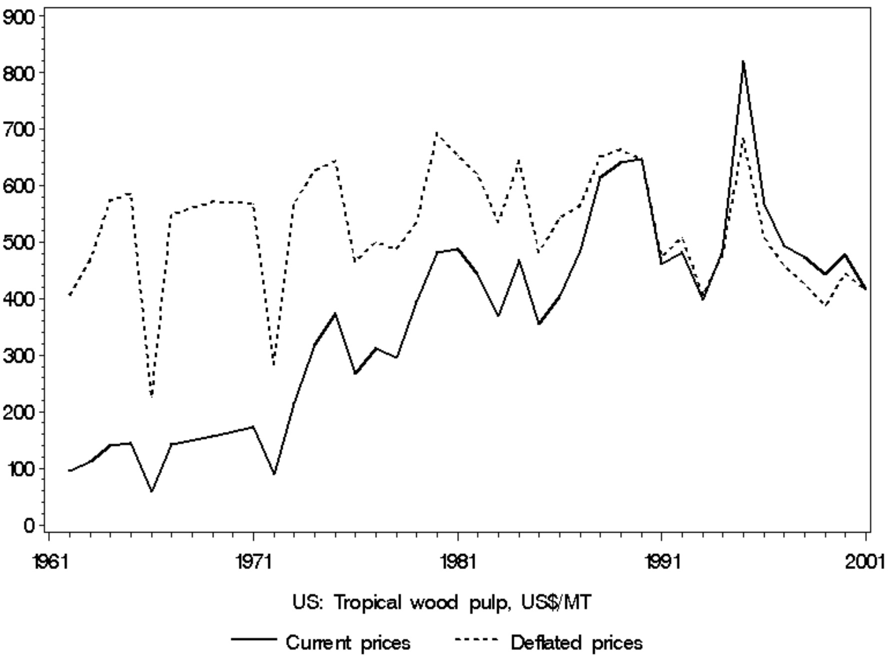

Figure A.81 Current and deflated prices of tropical wood pulp.

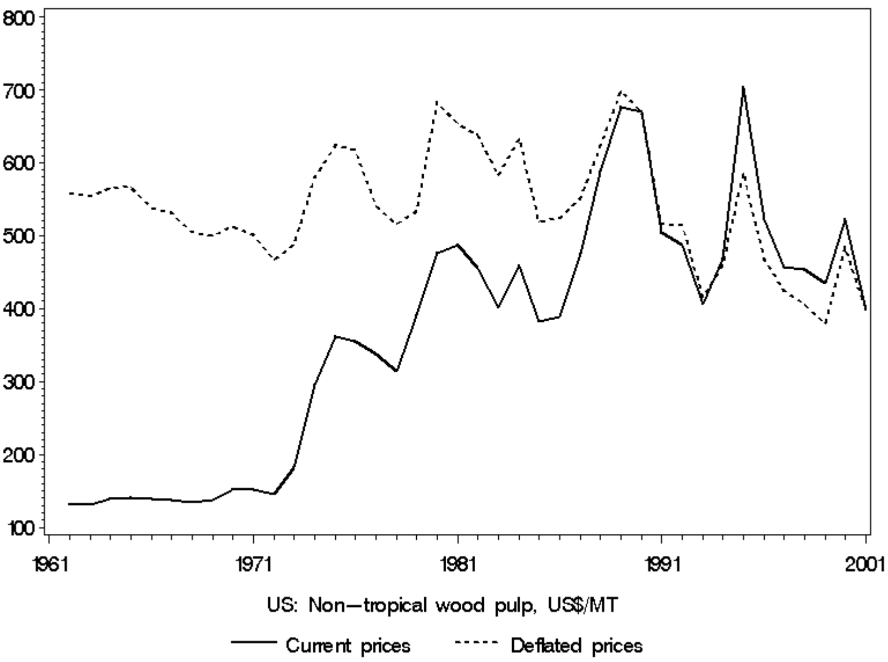

Figure A.82 Current and deflated prices of non-tropical wood pulp.

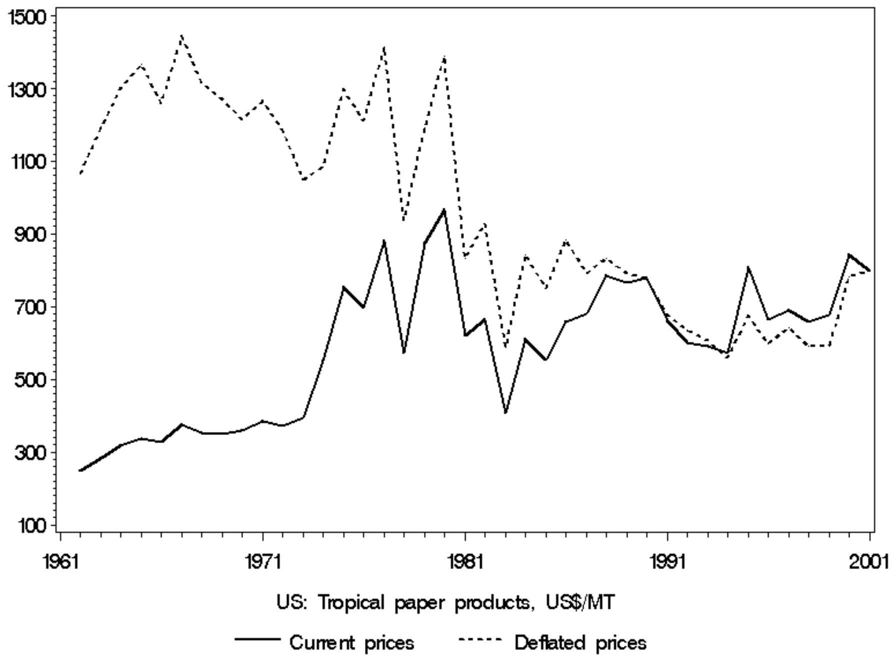

Figure A.83 Current and deflated prices of tropical paper products.

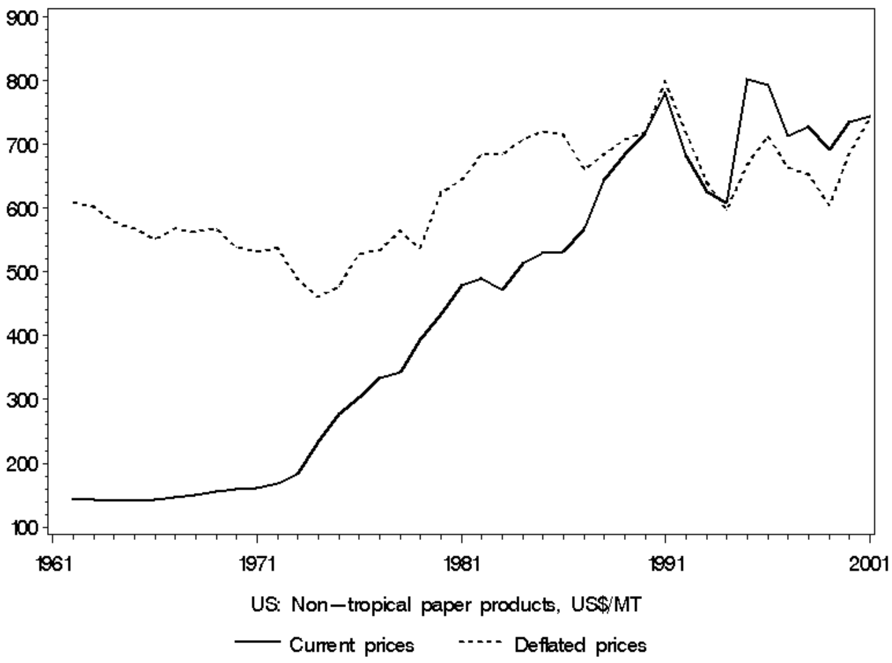

Figure A.84 Current and deflated prices of non-tropical paper products.

6.3 Cost shares

6.3.1 France

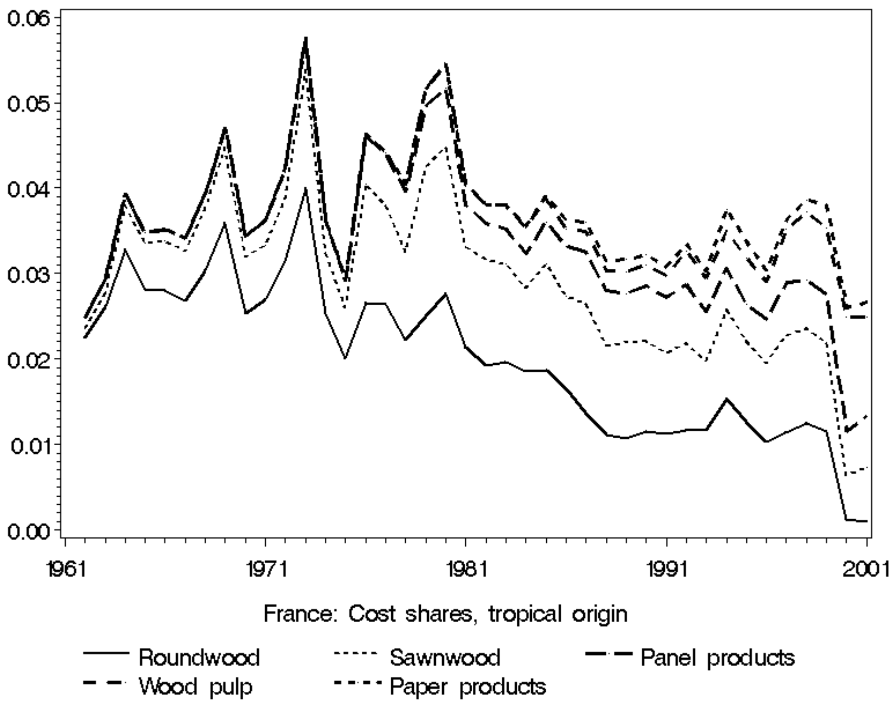

Figure A.85 Cost shares, tropical wood products.

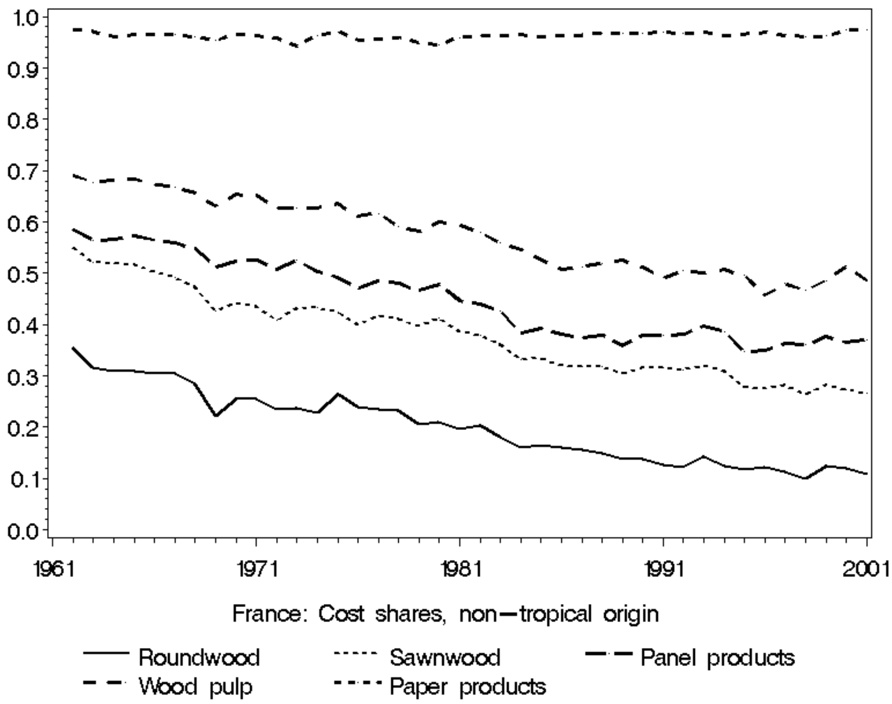

Figure A.86 Cost shares, non-tropical wood products.

6.3.2 Germany

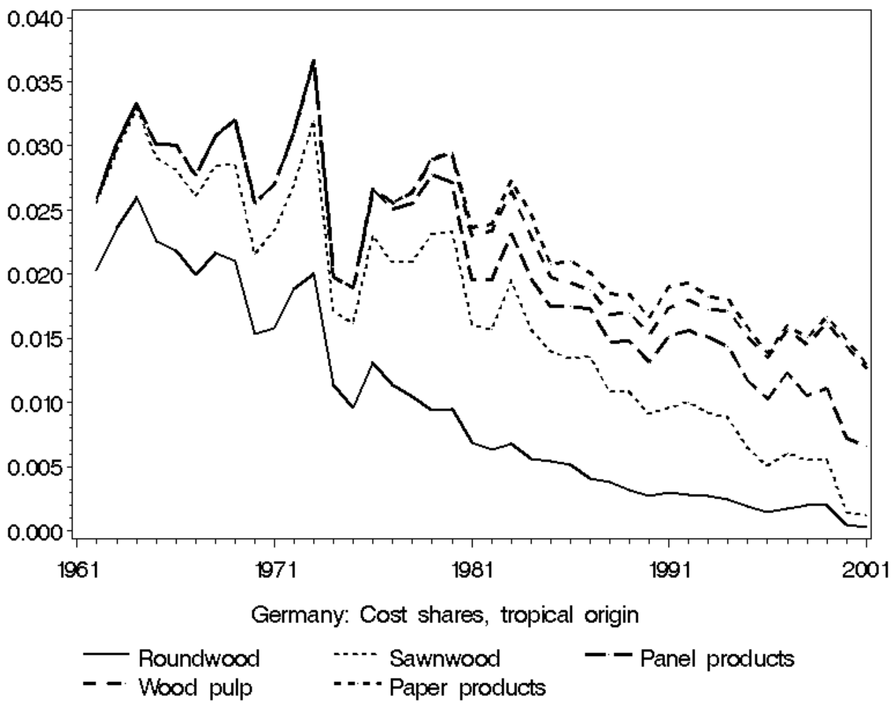

Figure A.87 Cost shares, tropical wood products.

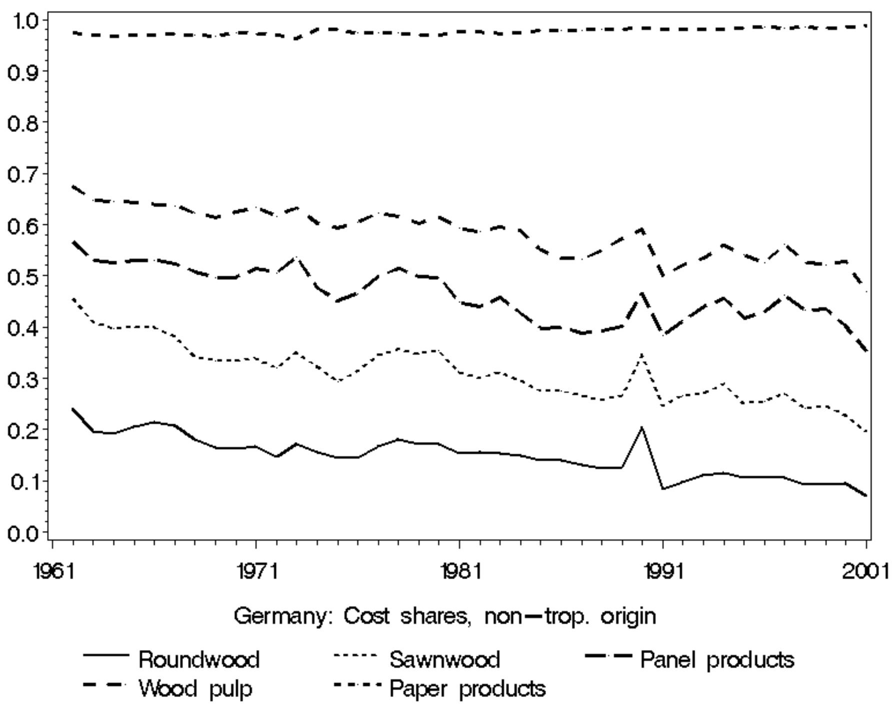

Figure A.88 Cost shares, non-tropical wood products.

6.3.3 Italy

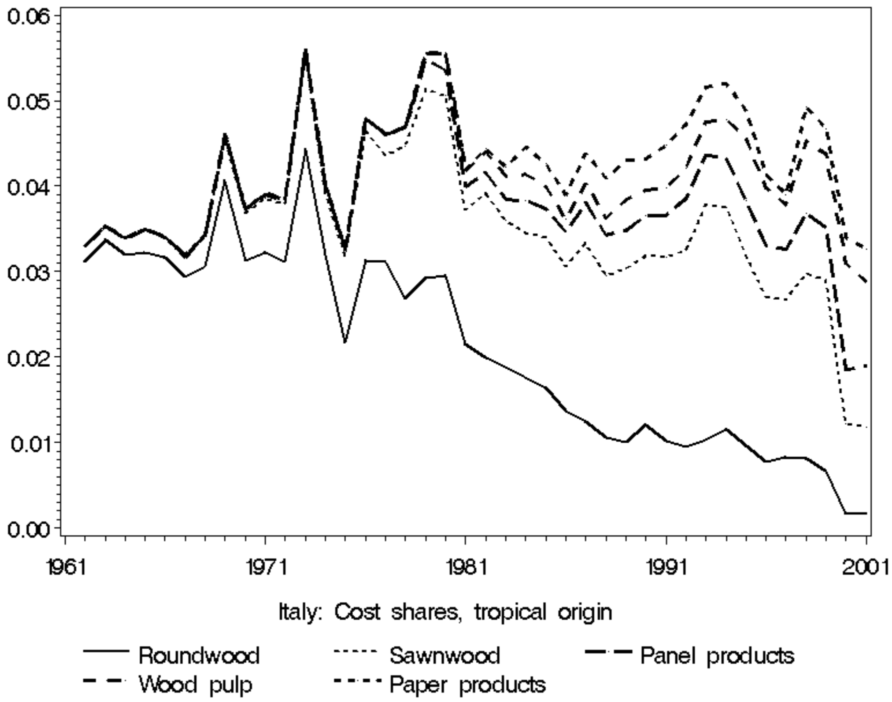

Figure A.89 Cost shares, tropical wood products.

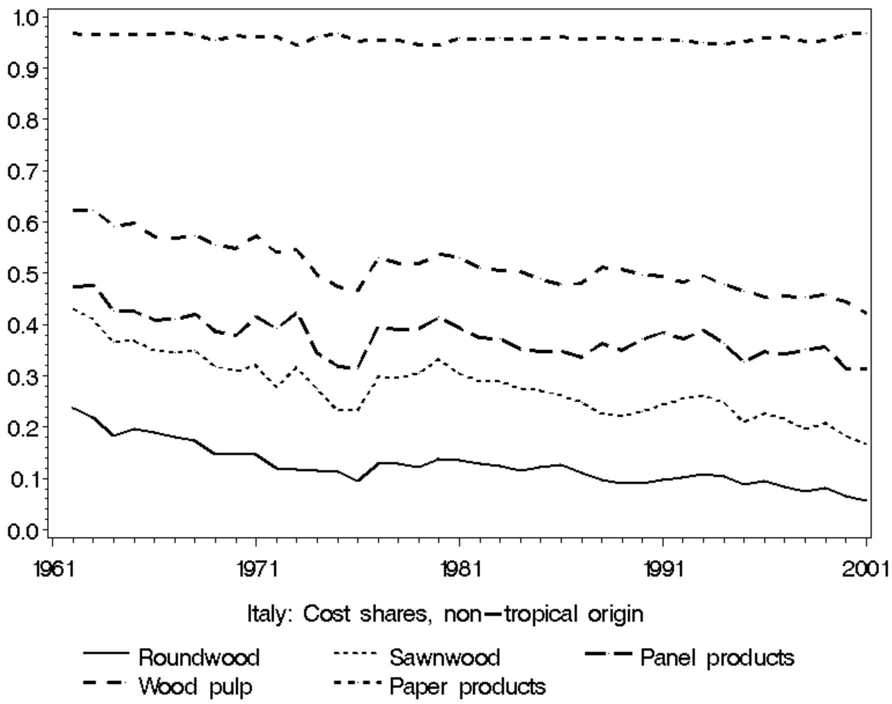

Figure A.90 Cost shares, non-tropical wood products.

6.3.4 Japan

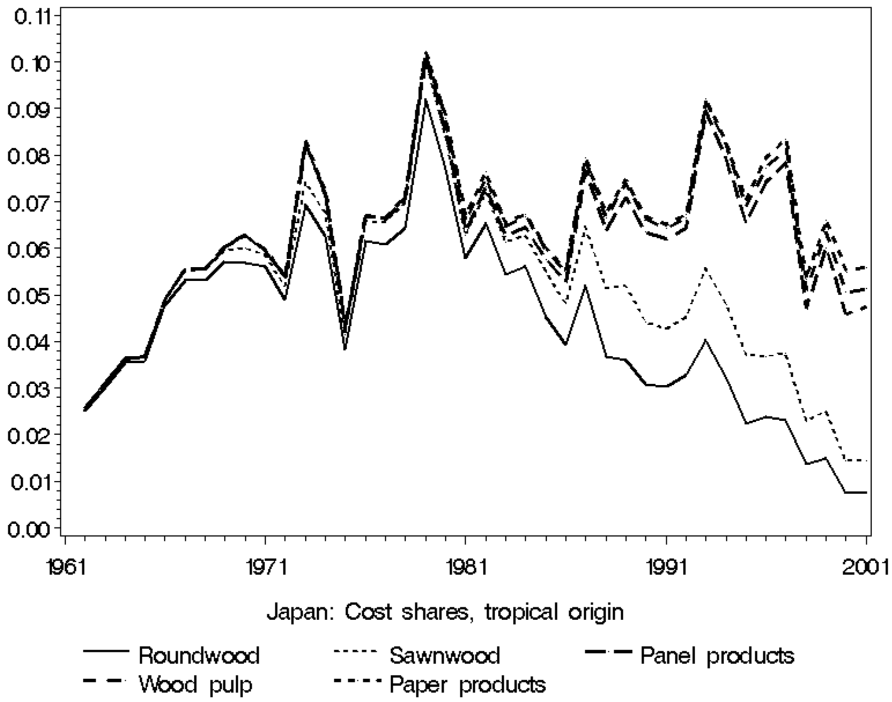

Figure A.91 Cost shares, tropical wood products.

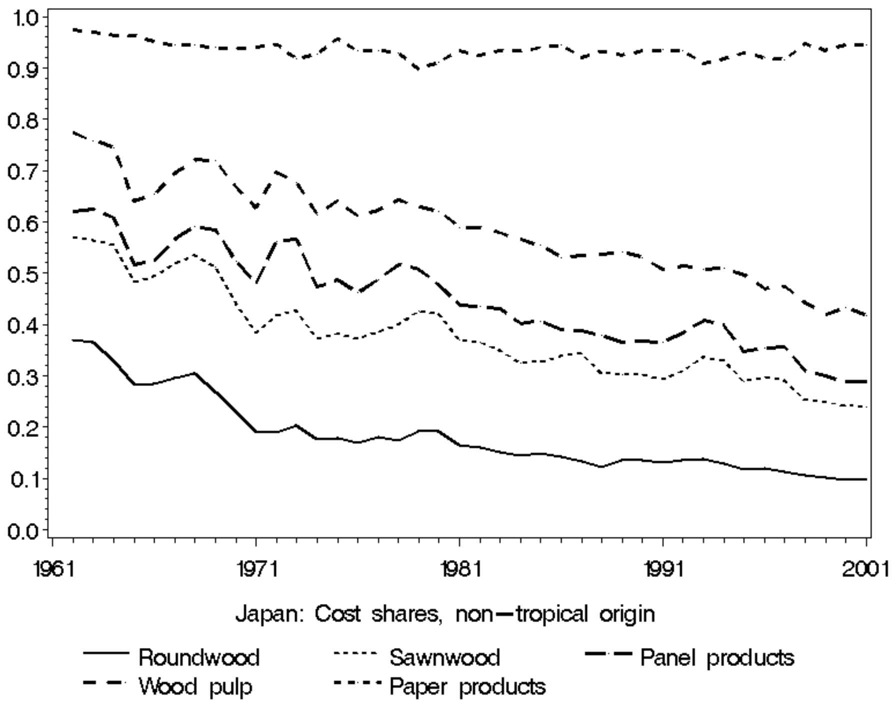

Figure A.92 Cost shares, non-tropical wood products.

6.3.5 United Kingdom

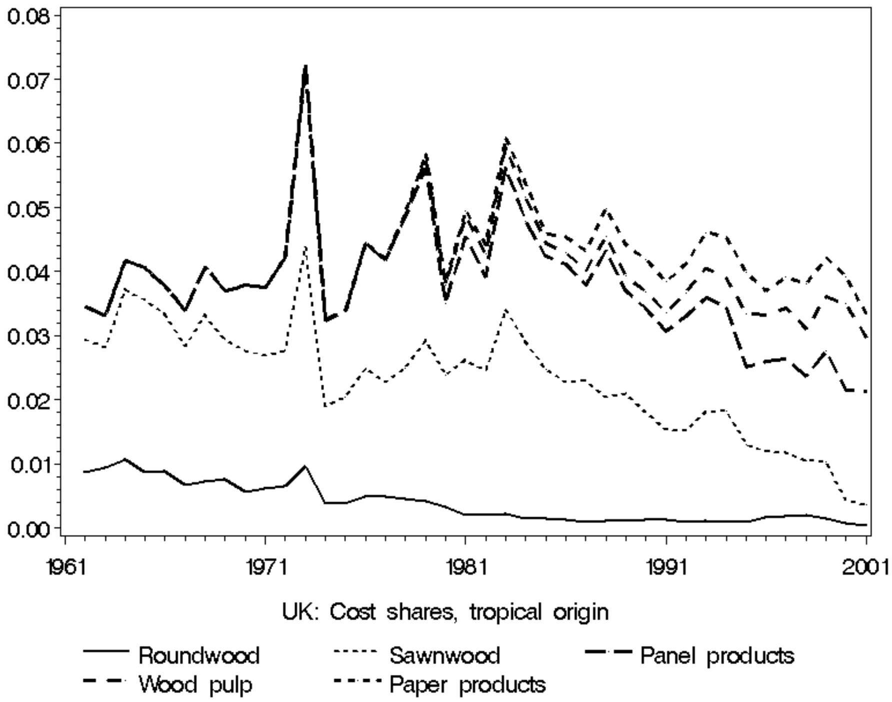

Figure A.93 Cost shares, tropical wood products.

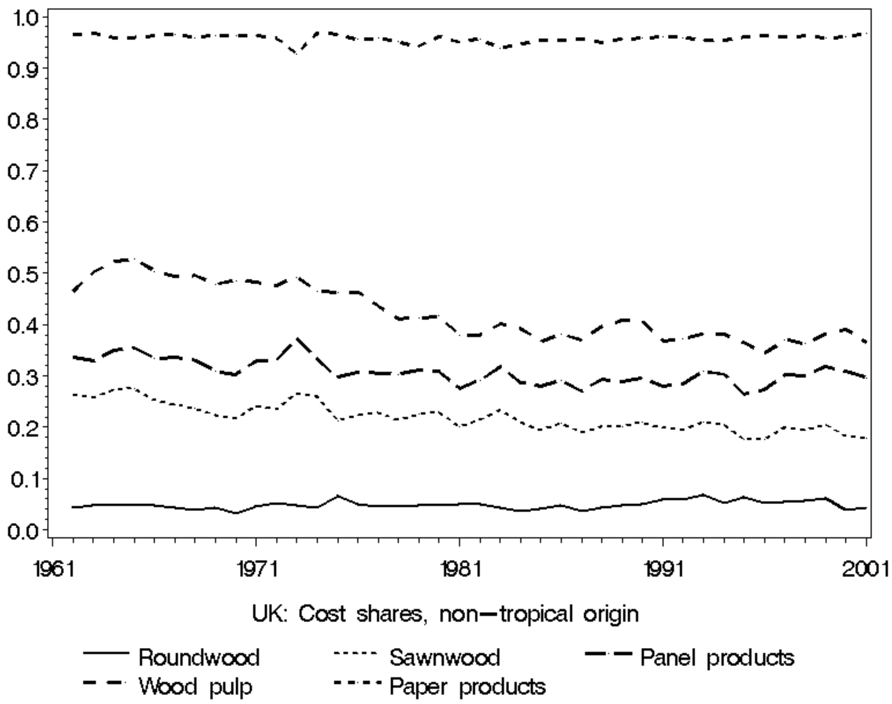

Figure A.94 Cost shares, non-tropical forest products.

6.3.6 United States

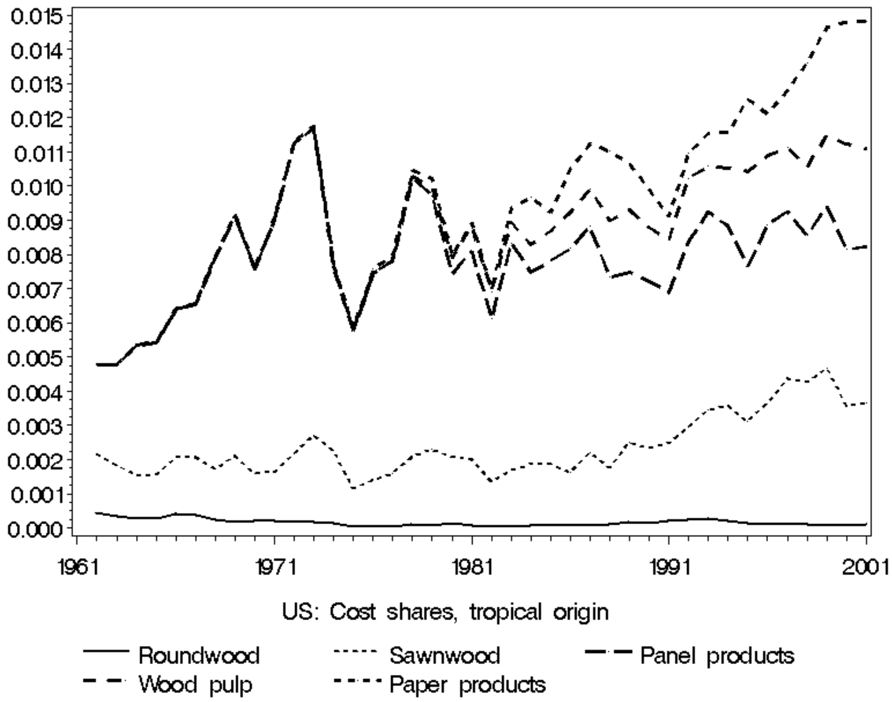

Figure A.95 Cost shares, tropical wood products.

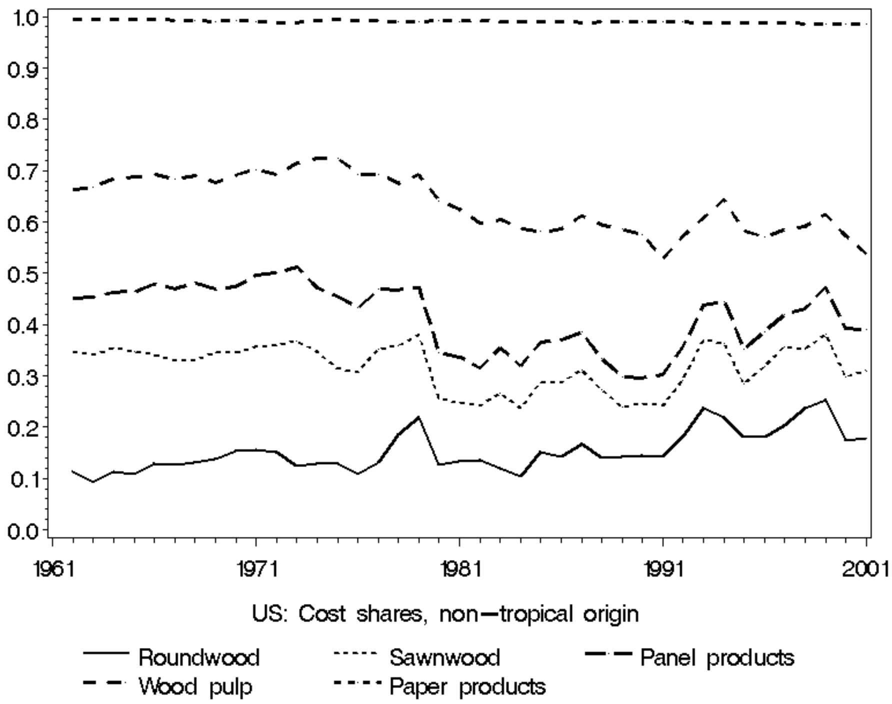

Figure A.96 Cost shares, non-tropical wood products.

Appendix B – Elasticities

The first part of this appendix presents tables with the Morishima's and McFadden's elasticities of substitution for each of the six countries covered by the analysis. The elasticities are computed by mean values of the cost shares for the time period 1977-2001. Standard errors assume non-stochastic cost shares and should therefore be regarded as low estimates. The elasticities are given in bold types and the approximate standard errors are in normal types.

The second part presents how the McFadden's elasticities of substitution develop over time. For each country five graphs are displayed; the first presents substitution within each of the five aggregates, and the subsequent graphs present substitutions between the aggregates. The range around zero is the most interesting to explore and therefore some observations are kept out of the range of the graphs.

The following abbreviations are applied:

TRW	Tropical Roundwood
NTRW	Non-tropical Roundwood
TSW	Tropical Sawnwood
NTSW	Non-tropical Sawnwood
TWP	Tropical Panel Products
NTWP	Non-tropical Panel Products
TPU	Tropical Wood Pulp
NTPU	Non-tropical Wood Pulp
TPP	Tropical Paper Products
NTPP	Non-tropical Paper Products

Appendix contents:

6.4 France

Table B.1 Own-price and cross price elasticities for France.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood	**0,145**	**-0,476**	**0,011**	**0,173**	**0,006**	**0,070**	**-0,360**	**0,699**		
	0,138	0,227	0,000	0,000	0,000	0,000	0,059	0,155		
Non-tropical Roundwood	**-0,046**	**-0,203**	**0,011**	**0,173**	**0,006**	**0,070**	**0,004**	**0,129**		
	0,022	0,102	0,000	0,000	0,000	0,000	0,000	0,000		
Tropical Sawnwood	**0,015**	**0,154**	**0,373**	**-1,193**						
	0,000	0,000	0,402	0,530						
Non-tropical Sawnwood	**0,015**	**0,154**	**-0,075**	**-0,083**						
	0,000	0,000	0,033	0,087						
Tropical Panels	**0,015**	**0,154**			**-0,994**	**0,070**				
	0,000	0,000			0,000	0,000				
Non-tropical Panels	**0,015**	**0,154**			**0,006**	**-0,239**				
	0,000	0,000			0,000	0,258				
Tropical Wood Pulp	**-1,310**	**0,154**					**-0,996**	**0,129**	**0,373**	**0,437**
	0,215	0,000					0,000	0,000	0,152	0,000
Non-tropical Wood Pulp	**0,081**	**0,154**					**0,004**	**0,113**	**0,001**	**-0,154**
	0,018	0,000					0,000	0,069	0,000	0,096
Tropical Papers							**1,631**	**0,129**	**-0,999**	**0,437**
							0,663	0,000	0,000	0,000
Non-tropical Papers							**0,004**	**-0,045**	**0,001**	**-0,097**
							0,000	0,028	0,000	0,086

Table B.2 Morishima's elasticities of substitution for France, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**-0,273** 0,246	**-0,362** 0,402	**0,256** 0,087	**1,000** 0,000	**0,310** 0,258	**0,636** 0,059	**0,586** 0,182		
Non-tropical Roundwood	**-0,191** 0,143		**-0,362** 0,402	**0,256** 0,087	**1,000** 0,000	**0,310** 0,258	**1,000** 0,000	**0,016** 0,069		
Tropical Sawnwood	**-0,131** 0,138	**0,357** 0,102		**-1,110** 0,536						
Non-tropical Sawnwood	**-0,131** 0,138	**0,357** 0,102	**-0,448** 0,415							
Tropical Panels	**-0,131** 0,138	**0,357** 0,102				**0,310** 0,258				
Non-tropical Panels	**-0,131** 0,138	**0,357** 0,102			**1,000** 0,000					
Tropical Wood Pulp	**-1,456** 0,185	**0,357** 0,102						**0,016** 0,069	**1,372** 0,152	**0,534** 0,086
Non-tropical Wood Pulp	**-0,065** 0,136	**0,357** 0,102					**1,000** 0,000		**1,000** 0,000	**-0,057** 0,148
Tropical Papers							**2,627** 0,663	**0,016** 0,069		**0,534** 0,086
Non-tropical Papers							**1,000** 0,000	**-0,158** 0,079	**1,000** 0,000	

Table B.3 McFadden's elasticities of substitution for France, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**-0,199** 0,138	**-0,264** 0,242	**-0,100** 0,128	**0,689** 0,038	**-0,054** 0,124	**0,186** 0,081	**0,003** 0,123		
Non-tropical Roundwood			**-0,315** 0,376	**0,309** 0,070	**0,977** 0,004	**0,324** 0,181	**0,983** 0,003	**0,171** 0,061		
Tropical Sawnwood				**-0,487** 0,406						
Non-tropical Sawnwood										
Tropical Panels						**0,949** 0,019				
Non-tropical Panels										
Tropical Wood Pulp								**0,970** 0,002	**1,606** 0,247	**0,996** 0,001
Non-tropical Wood Pulp									**0,993** 0,001	**-0,135** 0,081
Tropical Papers										**0,999** 0,000

6.5 Germany

Table B.4 Own-price and cross-price elasticities for France.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood	**-0,996**	**0,130**	**0,007**	**0,153**	**-0,247**	**0,151**	**0,004**	**0,129**		
	0,000	0,000	0,000	0,000	0,086	0,000	0,000	0,000		
Non-tropical Roundwood	**0,004**	**-0,870**	**0,007**	**0,153**	**0,045**	**0,151**	**0,004**	**0,129**		
	0,000	0,000	0,000	0,000	0,013	0,000	0,000	0,000		
Tropical Sawnwood	**0,004**	**0,130**	**-0,993**	**0,153**						
	0,000	0,000	0,000	0,000						
Non-tropical Sawnwood	**0,004**	**0,130**	**0,007**	**-0,166**						
	0,000	0,000	0,000	0,140						
Tropical Panels	**-0,237**	**1,258**			**-0,995**	**0,151**				
	0,083	0,352			0,000	0,000				
Non-tropical Panels	**0,004**	**0,130**			**0,005**	**-0,123**				
	0,000	0,000			0,000	0,160				
Tropical Wood Pulp	**0,004**	**0,130**					**-0,996**	**0,123**	**0,001**	**0,422**
	0,000	0,000					0,000	0,000	0,000	0,000
Non-tropical Wood Pulp	**0,004**	**0,130**					**0,004**	**0,040**	**0,001**	**-0,110**
	0,000	0,000					0,000	0,068	0,000	0,103
Tropical Papers							**0,004**	**0,129**	**-3,168**	**0,422**
							0,000	0,000	0,534	0,000
Non-tropical Papers							**0,004**	**-0,034**	**0,001**	**0,155**
							0,000	0,031	0,000	0,076

Table B.5 Morishima's elasticities of substitution for Germany, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**1,000** 0,000	**1,000** 0,000	**0,319** 0,140	**0,749** 0,086	**0,274** 0,160	**1,000** 0,000	**0,089** 0,068		
Non-tropical Roundwood	**1,000** 0,000		**1,000** 0,000	**0,319** 0,140	**1,040** 0,013	**0,274** 0,160	**1,000** 0,000	**0,089** 0,068		
Tropical Sawnwood	**1,000** 0,000	**1,000** 0,000		**0,319** 0,140						
Non-tropical Sawnwood	**1,000** 0,000	**1,000** 0,000	**1,000** 0,000							
Tropical Panels	**0,759** 0,083	**2,128** 0,352				**0,274** 0,160				
Non-tropical Panels	**1,000** 0,000	**1,000** 0,000			**1,000** 0,000					
Tropical Wood Pulp	**1,000** 0,000	**1,000** 0,000						**0,050** 0,071	**3,169** 0,534	**0,268** 0,076
Non-tropical Wood Pulp	**1,000** 0,000	**1,000** 0,000					**1,000** 0,000		**3,169** 0,534	**-0,265** 0,137
Tropical Papers							**1,000** 0,000	**0,089** 0,068		**0,268** 0,076
Non-tropical Papers							**1,000** 0,000	**-0,112** 0,085	**3,169** 0,534	

Table B.6 McFadden's elasticities of substitution for Germany, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**1,000** 0,000	**1,000** 0,000	**0,981** 0,004	**0,754** 0,085	**0,979** 0,005	**1,000** 0,000	**0,969** 0,002		
Non-tropical Roundwood			**1,000** 0,000	**0,687** 0,064	**1,078** 0,024	**0,665** 0,074	**1,000** 0,000	**0,542** 0,034		
Tropical Sawnwood				**0,969** 0,006						
Non-tropical Sawnwood										
Tropical Panels						**0,978** 0,005				
Non-tropical Panels										
Tropical Wood Pulp								**0,972** 0,002	**2,806** 0,445	**0,993** 0,001
Non-tropical Wood Pulp									**3,149** 0,531	**-0,118** 0,087
Tropical Papers										**3,163** 0,533

6.6 Italy

Table B.7 Own-price and cross-price elasticities for Italy.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood	**-0,634**	**-0,599**	**0,394**	**0,146**	**0,005**	**0,112**	**-0,201**	**0,127**		
	0,091	0,288	0,147	0,000	0,000	0,000	0,056	0,000		
Non-tropical Roundwood	**-0,081**	**-0,002**	**0,019**	**0,146**	**0,005**	**0,112**	**0,004**	**-0,116**		
	0,039	0,228	0,000	0,000	0,000	0,000	0,000	0,088		
Tropical Sawnwood	**0,292**	**0,105**	**0,927**	**0,146**						
	0,109	0,000	0,339	0,000						
Non-tropical Sawnwood	**0,014**	**0,105**	**0,019**	**-0,094**						
	0,000	0,000	0,000	0,169						
Tropical Panels	**0,014**	**0,105**			**-0,995**	**0,112**				
	0,000	0,000			0,000	0,000				
Non-tropical Panels	**0,014**	**0,105**			**0,005**	**0,200**				
	0,000	0,000			0,000	0,228				
Tropical Wood Pulp	**-0,703**	**0,105**					**-0,996**	**0,127**	**0,003**	**0,466**
	0,198	0,000					0,000	0,000	0,000	0,000
Non-tropical Wood Pulp	**0,014**	**-0,096**					**0,004**	**-0,170**	**0,003**	**0,100**
	0,000	0,072					0,000	0,066	0,000	0,104
Tropical Papers							**0,004**	**0,127**	**-0,997**	**0,466**
							0,000	0,000	0,000	0,000
Non-tropical Papers							**0,004**	**0,027**	**0,003**	**-0,133**
							0,000	0,028	0,000	0,082

Table B.8 Morishima's elasticities of substitution for Italy, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**-0,597** 0,444	**-0,533** 0,317	**0,240** 0,169	**1,000** 0,000	**-0,088** 0,228	**0,795** 0,056	**0,296** 0,066		
Non-tropical Roundwood	**0,552** 0,115		**-0,908** 0,339	**0,240** 0,169	**1,000** 0,000	**-0,088** 0,228	**1,000** 0,000	**0,053** 0,121		
Tropical Sawnwood	**0,926** 0,111	**0,106** 0,228		**0,240** 0,169						
Non-tropical Sawnwood	**0,648** 0,091	**0,106** 0,228	**-0,908** 0,339							
Tropical Panels	**0,648** 0,091	**0,106** 0,228				**-0,088** 0,228				
Non-tropical Panels	**0,648** 0,091	**0,106** 0,228			**1,000** 0,000					
Tropical Wood Pulp	**-0,070** 0,189	**0,106** 0,228						**0,296** 0,066	**1,000** 0,000	**0,599** 0,082
Non-tropical Wood Pulp	**0,648** 0,091	**-0,094** 0,247					**1,000** 0,000		**1,000** 0,000	**0,233** 0,153
Tropical Papers							**1,000** 0,000	**0,296** 0,066		**0,599** 0,082
Non-tropical Papers							**1,000** 0,000	**0,197** 0,078	**1,000** 0,000	

Table B.9 McFadden's elasticities of substitution for Italy, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**0,415** 0,139	**0,305** 0,150	**0,612** 0,084	**0,913** 0,022	**0,565** 0,086	**0,603** 0,084	**0,612** 0,082		
Non-tropical Roundwood			**-0,751** 0,290	**0,162** 0,162	**0,962** 0,010	**0,012** 0,174	**0,967** 0,008	**-0,027** 0,163		
Tropical Sawnwood				**-0,774** 0,307						
Non-tropical Sawnwood										
Tropical Panels						**0,957** 0,009				
Non-tropical Panels										
Tropical Wood Pulp								**0,978** 0,002	**1,000** 0,000	**0,997** 0,001
Non-tropical Wood Pulp									**0,986** 0,317	**0,205** 0,084
Tropical Papers										**0,998** 0,000

6.7 Japan

Table B.10 Own-price and cross-price elasticities for Japan.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood	**-0,282**	**0,138**	**0,183**	**0,185**	**0,269**	**-0,156**	**-0,028**	**-0,057**		
	0,172	0,000	0,059	0,000	0,110	0,098	0,011	0,084		
Non-tropical Roundwood	**0,041**	**-0,418**	**0,010**	**0,012**	**0,017**	**-0,038**	**0,002**	**0,050**		
	0,000	0,094	0,000	0,077	0,000	0,037	0,000	0,035		
Tropical Sawnwood	**0,721**	**0,138**	**-2,333**	**1,402**						
	0,233	0,000	0,478	0,518						
Non-tropical Sawnwood	**0,041**	**0,009**	**0,078**	**0,035**						
	0,000	0,057	0,029	0,086						
Tropical Panels	**0,662**	**0,138**			**-0,983**	**0,068**				
	0,270	0,000			0,000	0,000				
Non-tropical Panels	**-0,093**	**-0,077**			**0,017**	**-0,065**				
	0,058	0,075			0,000	0,065				
Tropical Wood Pulp	**-0,463**	**0,138**					**-0,998**	**1,094**	**0,001**	**-1,116**
	0,186	0,000					0,000	0,304	0,000	0,365
Non-tropical Wood Pulp	**-0,017**	**0,050**					**0,020**	**-0,023**	**0,001**	**-0,008**
	0,025	0,034					0,005	0,026	0,000	0,000
Tropical Papers							**0,002**	**0,139**	**-0,999**	**0,398**
							0,000	0,000	0,000	0,000
Non-tropical Papers							**-0,007**	**-0,003**	**0,001**	**0,079**
							0,002	0,014	0,000	0,037

Table B.11 Morishima's elasticities of substitution for Japan, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**0,556**	**2,515**	**0,150**	**1,253**	**-0,091**	**0,969**	**-0,034**		
		0,094	0,503	0,086	0,110	0,115	0,011	0,084		
Non-tropical Roundwood	**0,322**		**2,343**	**-0,023**	**1,000**	**0,026**	**1,000**	**0,073**		
	0,172		0,478	0,142	0,000	0,085	0,000	0,046		
Tropical Sawnwood	**1,003**	**0,556**		**1,367**						
	0,358	0,094		0,526						
Non-tropical Sawnwood	**0,322**	**0,427**	**2,411**							
	0,172	0,131	0,493							
Tropical Panels	**0,943**	**0,556**				**0,133**				
	0,377	0,094				0,065				
Non-tropical Panels	**0,189**	**0,341**			**1,000**					
	0,178	0,133			0,000					
Tropical Wood Pulp	**-0,181**	**0,556**						**1,117**	**1,000**	**-1,195**
	0,253	0,094						0,308	0,000	0,362
Non-tropical Wood Pulp	**0,265**	**0,468**					**1,017**		**1,000**	**-0,087**
	0,174	0,104					0,005		0,000	0,051
Tropical Papers							**1,000**	**0,162**		**0,320**
							0,000	0,026		0,037
Non-tropical Papers							**0,991**	**0,020**	**1,000**	
							0,002	0,030	0,000	

Table B.12 McFadden's elasticities of substitution for Japan, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**0,375**	**2,210**	**0,291**	**1,163**	**0,085**	**0,903**	**0,197**		
		0,138	0,432	0,144	0,183	0,128	0,024	0,138		
Non-tropical Roundwood			**2,219**	**0,235**	**0,953**	**0,130**	**0,992**	**0,271**		
			0,445	0,123	0,010	0,088	0,002	0,065		
Tropical Sawnwood				**2,356**						
				0,482						
Non-tropical Sawnwood										
Tropical Panels						**0,831**				
						0,013				
Non-tropical Panels										
Tropical Wood Pulp								**1,019**	**1,000**	**0,977**
								0,011	0,000	0,005
Non-tropical Wood Pulp									**0,993**	**-0,007**
									0,000	0,031
Tropical Papers										**0,998**
										0,000

6.8 United Kingdom

Table B.13 Own-price and cross-price elasticities for the United Kingdom.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood	**-0,998**	**0,049**	**-1,117**	**2,230**	**0,017**	**0,091**	**-0,557**	**0,091**		
	0,000	0,000	0,421	0,851	0,000	0,000	0,268	0,000		
Non-tropical Roundwood	**0,002**	**-0,032**	**0,174**	**-0,481**	**0,017**	**0,091**	**0,004**	**0,091**		
	0,000	0,082	0,072	0,219						
Tropical Sawnwood	**-0,115**	**0,497**	**-1,904**	**2,095**						
	0,044	0,207	0,398	0,797						
Non-tropical Sawnwood	**0,026**	**-0,155**	**0,236**	**0,090**						
	0,010	0,070	0,090	0,371						
Tropical Panels	**0,002**	**0,049**			**-0,983**	**0,091**				
	0,000	0,000			0,000	0,000				
Non-tropical Panels	**0,002**	**0,049**			**0,017**	**-0,316**				
	0,000	0,000			0,000	0,105				
Tropical Wood Pulp	**-0,229**	**0,049**					**-0,996**	**0,091**	**0,003**	**0,570**
	0,110	0,000					0,000	0,000	0,000	0,000
Non-tropical Wood Pulp	**0,002**	**0,049**					**0,004**	**0,097**	**0,003**	**-0,080**
							0,000	0,124	0,000	0,224
Tropical Papers							**0,004**	**0,091**	**0,955**	**0,570**
							0,000	0,000	0,671	0,000
Non-tropical Papers							**0,004**	**-0,013**	**0,003**	**-0,083**
							0,000	0,036	0,000	0,121

Table B.14 Morishima's elasticities of substitution for United Kingdom, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**0,081** 0,082	**0,787** 0,667	**2,139** 0,793	**1,000** 0,000	**0,408** 0,105	**0,439** 0,268	**-0,006** 0,124		
Non-tropical Roundwood	**1,000** 0,000		**2,078** 0,403	**-0,572** 0,420	**1,000** 0,000	**0,408** 0,105	**1,000** 0,000	**-0,006** 0,124		
Tropical Sawnwood	**0,883** 0,044	**0,529** 0,241		**2,005** 1,059						
Non-tropical Sawnwood	**1,024** 0,010	**-0,123** 0,105	**2,140** 0,455							
Tropical Panels	**1,000** 0,000	**0,081** 0,082				**0,408** 0,105				
Non-tropical Panels	**1,000** 0,000	**0,081** 0,082			**1,000** 0,000					
Tropical Wood Pulp	**0,770** 0,110	**0,081** 0,082						**-0,006** 0,124	**-0,952** 0,671	**0,653** 0,121
Non-tropical Wood Pulp	**1,000** 0,000	**0,081** 0,082					**1,000** 0,000		**-0,952** 0,671	**0,002** 0,303
Tropical Papers							**1,000** 0,000	**-0,006** 0,124		**0,653** 0,121
Non-tropical Papers							**1,000** 0,000	**-0,110** 0,145	**-0,952** 0,671	

Table B.15 McFadden's elasticities of substitution for United Kingdom, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**0,968** 0,003	**0,874** 0,098	**1,037** 0,018	**1,000** 0,000	**0,989** 0,002	**0,673** 0,156	**0,981** 0,002		
Non-tropical Roundwood			**1,677** 0,316	**-0,232** 0,148	**0,761** 0,022	**0,196** 0,065	**0,926** 0,007	**0,051** 0,070		
Tropical Sawnwood				**2,126** 0,485						
Non-tropical Sawnwood										
Tropical Panels						**0,905** 0,017				
Non-tropical Panels										
Tropical Wood Pulp								**0,954** 0,006	**-0,087** 0,374	**0,997** 0,001
Non-tropical Wood Pulp									**-0,917** 0,647	**-0,095** 0,153
Tropical Papers										**-0,942** 0,667

6.9 United States

Table B.16 Own-price and cross-price elasticities for the United States.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood	**-1,000**	**0,169**	**0,003**	**0,133**	**0,006**	**0,079**	**-2,356**	**0,222**		
	0,000	0,000	0,000	0,000	0,000	0,000	0,516	0,000		
Non-tropical Roundwood	**0,000**	**-0,030**	**0,003**	**-0,002**	**0,006**	**0,003**	**0,001**	**-0,024**		
	0,000	0,041	0,000	0,039	0,000	0,029	0,000	0,034		
Tropical Sawnwood	**0,000**	**0,169**	**-0,585**	**0,133**						
	0,000	0,000	0,139	0,000						
Non-tropical Sawnwood	**0,000**	**-0,002**	**0,003**	**-0,051**						
	0,000	0,049	0,000	0,076						
Tropical Panels	**0,000**	**0,169**			**-0,994**	**0,079**				
	0,000	0,000			0,000	0,000				
Non-tropical Panels	**0,000**	**0,005**			**0,006**	**0,017**				
	0,000	0,062			0,000	0,119				
Tropical Wood Pulp	**-0,190**	**0,169**					**0,577**	**0,222**	**0,001**	**0,387**
	0,042	0,000					0,300	0,000	0,000	0,000
Non-tropical Wood Pulp	**0,000**	**-0,018**					**0,001**	**-0,054**	**0,001**	**0,019**
	0,000	0,026					0,000	0,047	0,000	0,048
Tropical Papers							**0,001**	**0,222**	**-0,131**	**0,387**
							0,000	0,000	0,303	0,000
Non-tropical Papers							**0,001**	**0,011**	**0,001**	**0,041**
							0,000	0,027	0,000	0,042

Table B.17 Morishima's elasticities of substitution for United States, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**0,198**	**0,587**	**0,184**	**1,000**	**0,062**	**-2,933**	**0,275**		
		0,041	0,139	0,076	0,000	0,119	0,422	0,047		
Non-tropical Roundwood	**1,000**		**0,587**	**0,049**	**1,000**	**-0,015**	**-0,576**	**0,030**		
	0,000		0,139	0,104	0,000	0,131	0,300	0,051		
Tropical Sawnwood	**1,000**	**0,198**		**0,184**						
	0,000	0,041		0,076						
Non-tropical Sawnwood	**1,000**	**0,028**	**0,587**							
	0,000	0,081	0,139							
Tropical Panels	**1,000**	**0,198**				**0,062**				
	0,000	0,041				0,119				
Non-tropical Panels	**1,000**	**0,035**			**1,000**					
	0,000	0,089			0,000					
Tropical Wood Pulp	**0,810**	**0,198**						**0,275**	**0,133**	**0,346**
	0,042	0,041						0,047	0,303	0,042
Non-tropical Wood Pulp	**1,000**	**0,011**					**-0,576**		**0,133**	**-0,022**
	0,000	0,043					0,300		0,303	0,084
Tropical Papers							**-0,576**	**0,275**		**0,346**
							0,300	0,047		0,042
Non-tropical Papers							**-0,576**	**0,064**	**0,133**	
							0,300	0,068	0,303	

Table B.18 McFadden's elasticities of substitution for United States, 1977-2001.

	Tropical Roundwood	Non-tropical Roundwood	Tropical Sawnwood	Non-tropical Sawnwood	Tropical Panels	Non-tropical Panels	Tropical Wood Pulp	Non-tropical Wood Pulp	Tropical Papers	Non-tropical Papers
Tropical Roundwood		**0,999**	**0,983**	**0,999**	**1,000**	**0,999**	**0,530**	**1,000**		
		0,000	0,006	0,000	0,000	0,000	0,067	0,000		
Non-tropical Roundwood			**0,581**	**0,040**	**0,975**	**0,001**	**-0,569**	**0,019**		
			0,137	0,087	0,001	0,105	0,297	0,035		
Tropical Sawnwood				**0,580**						
				0,137						
Non-tropical Sawnwood										
Tropical Panels						**0,938**				
						0,008				
Non-tropical Panels										
Tropical Wood Pulp								**-0,570**	**-0,207**	**-0,570**
								0,298	0,222	0,299
Non-tropical Wood Pulp									**0,134**	**0,033**
									0,301	0,069
Tropical Papers										**0,133**
										0,302

6.10 Substitution within aggregates

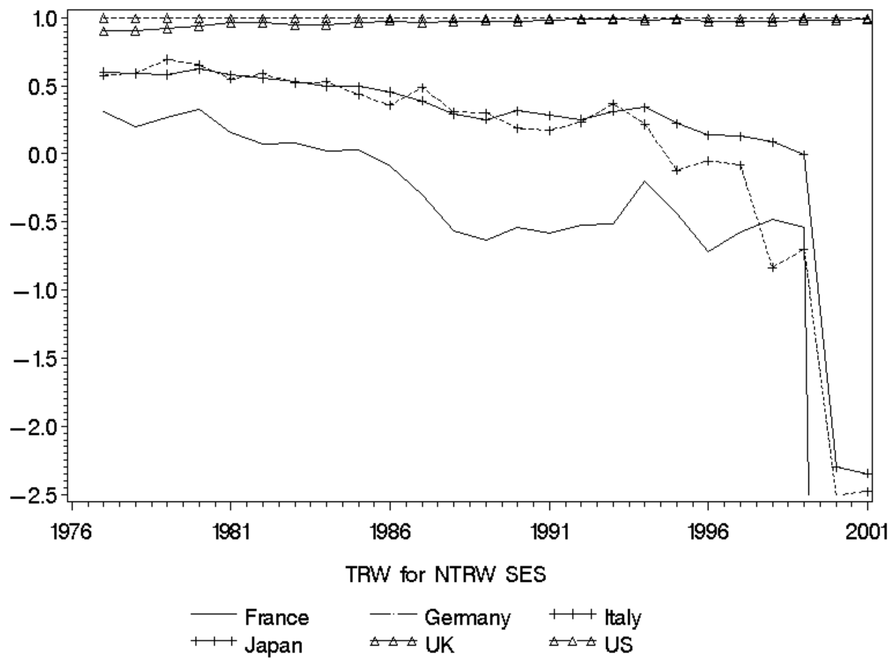

Figure B.1 Tropical Roundwood and Non-tropical Roundwood substitution, measured by Mc Fadden's shadow elasticity of substitution.

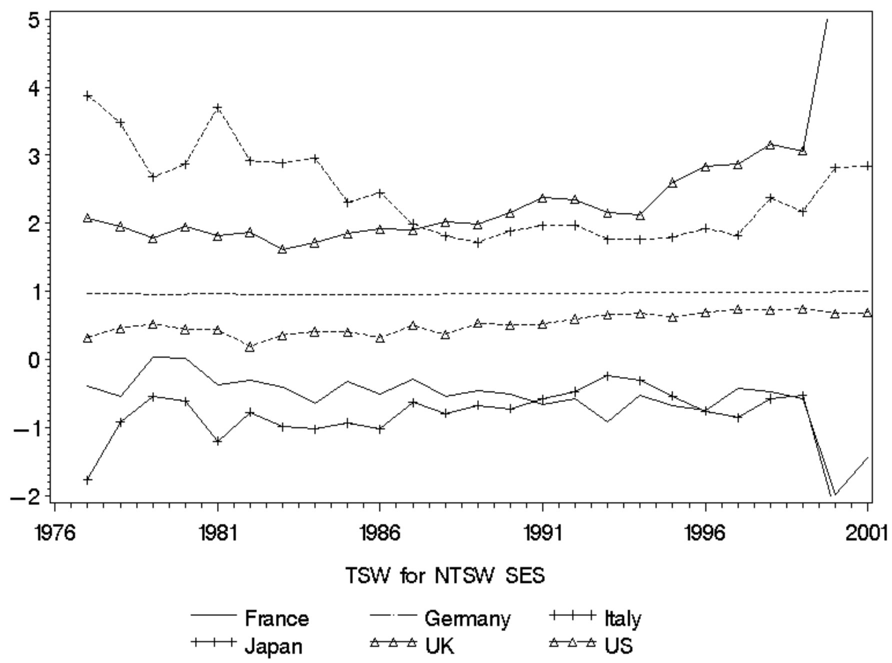

Figure B.2 Tropical Sawnwood and Non-tropical Sawnwood substitution, measured by McFadden's shadow elasticity of substitution.

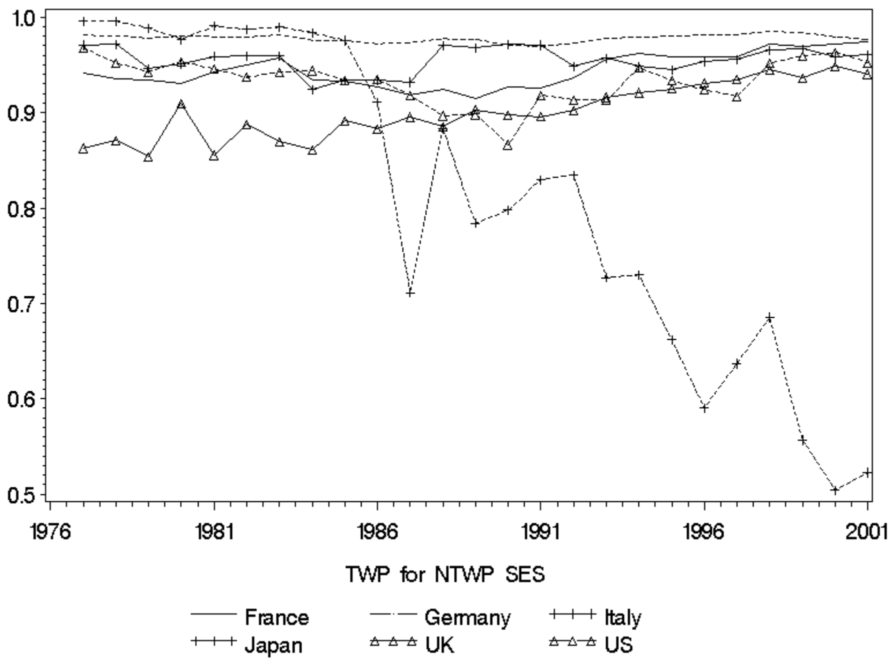

Figure B.3 Tropical Panels and Non-tropical Panels substitution, measured by McFadden's shadow elasticity of substitution.

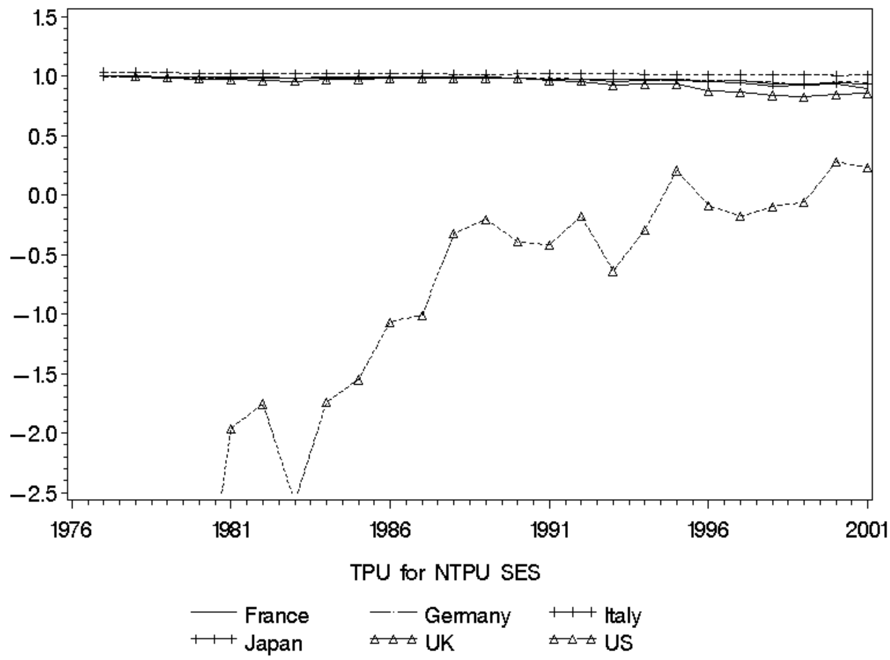

Figure B.4 Tropical Wood Pulp and Non-tropical Wood Pulp substitution, measured by McFadden's shadow elasticity of substitution.

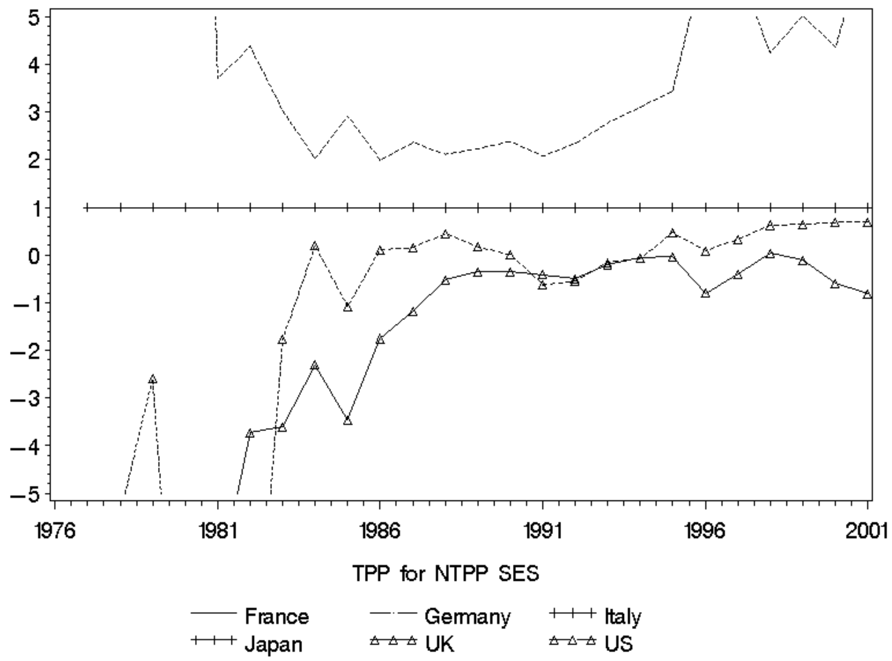

Figure B.5 Tropical Papers and Non-tropical papers substitution, measured by McFadden's shadow elasticity of substitution.

6.11 Substitution between aggregates

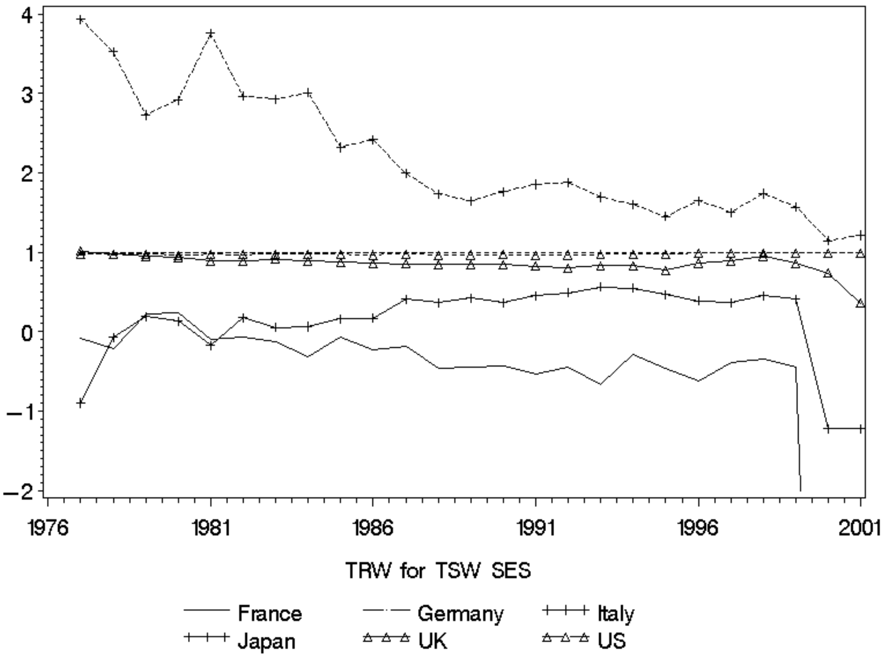

Figure B.6 Tropical Roundwood for Tropical Sawnwood substitution, measured by McFadden's shadow elasticity of substitution.

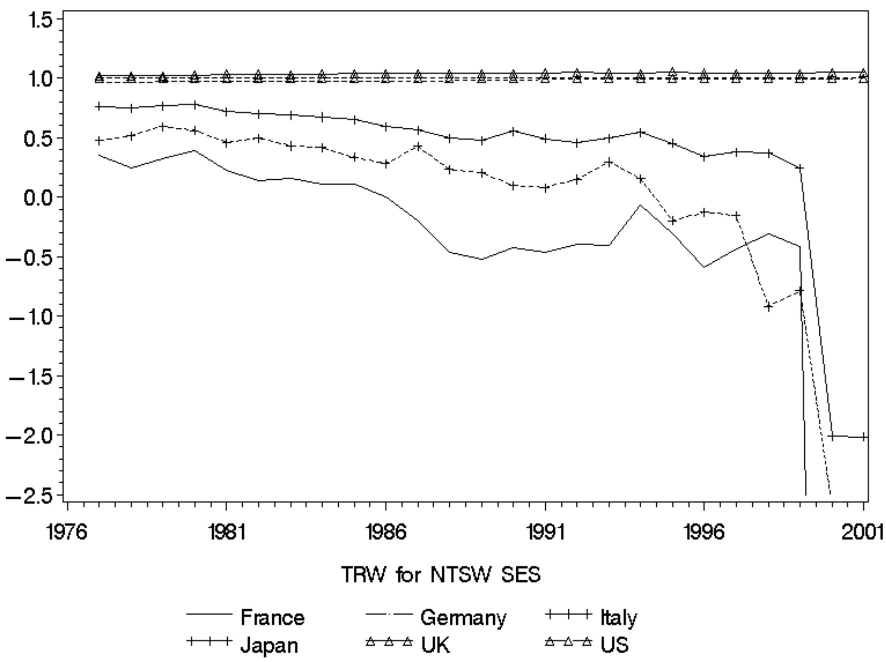

Figure B.7 Tropical Roundwood and Non-tropical Sawnwood substitution, measured by McFadden's shadow elasticity of substitution.

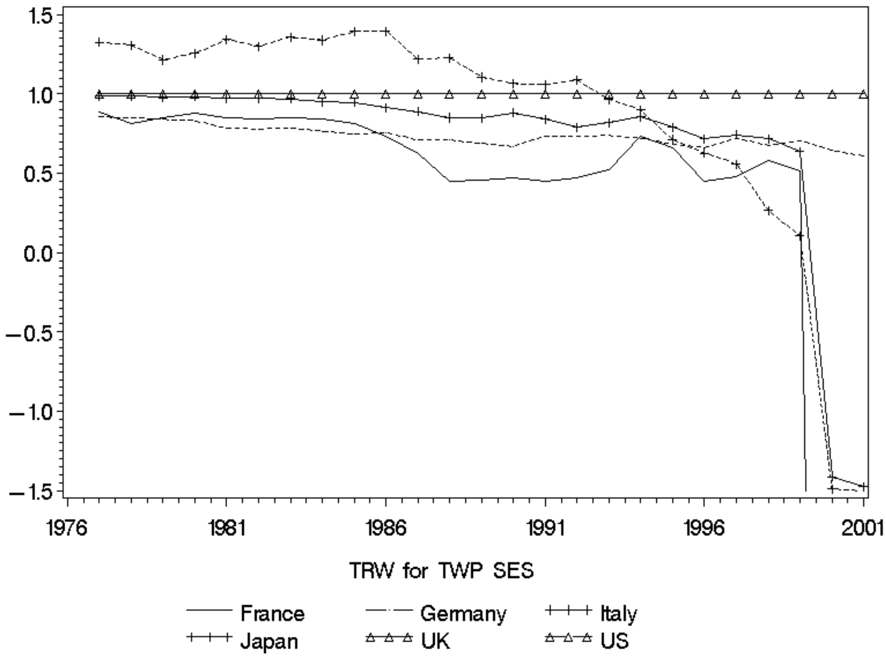

Figure B.8 Tropical Roundwood and Tropical Panels substitution, measured by McFadden's shadow elasticity of substitution.

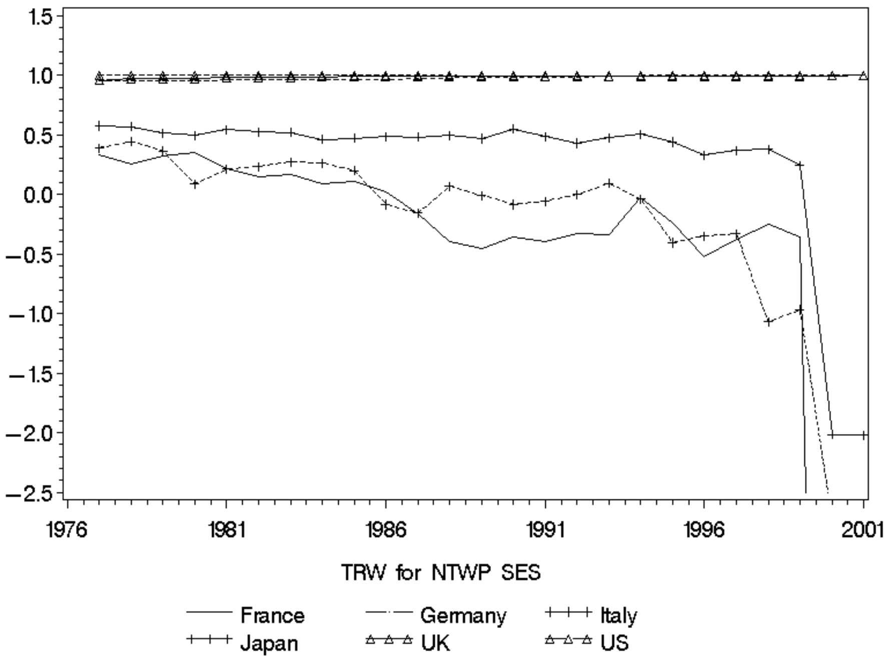

Figure B.9 Tropical Roundwood and Non-tropical Panels substitution, measured by McFadden's shadow elasticity of substitution.

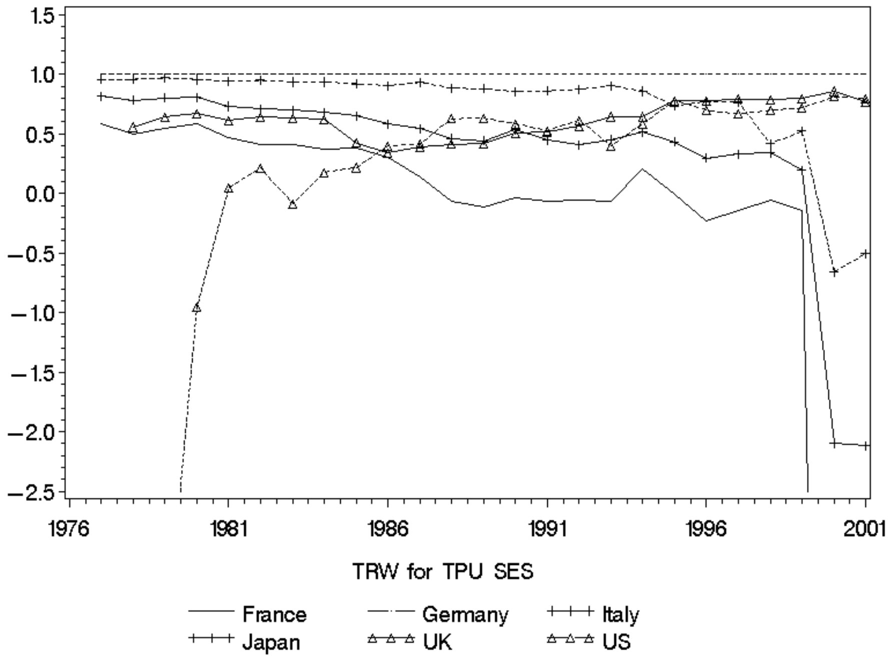

Figure B.10 Tropical Roundwood and Tropical Wood Pulp substitution, measured by McFadden's shadow elasticity of substitution.

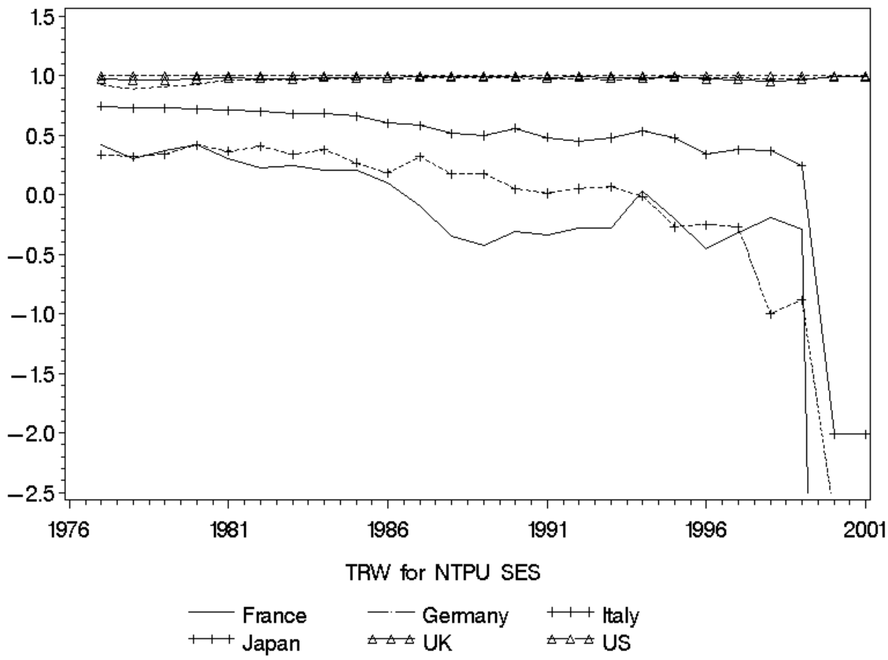

Figure B.11 Tropical Roundwood and Non-tropical Wood Pulp substitution, measured by McFadden's shadow elasticity of substitution.

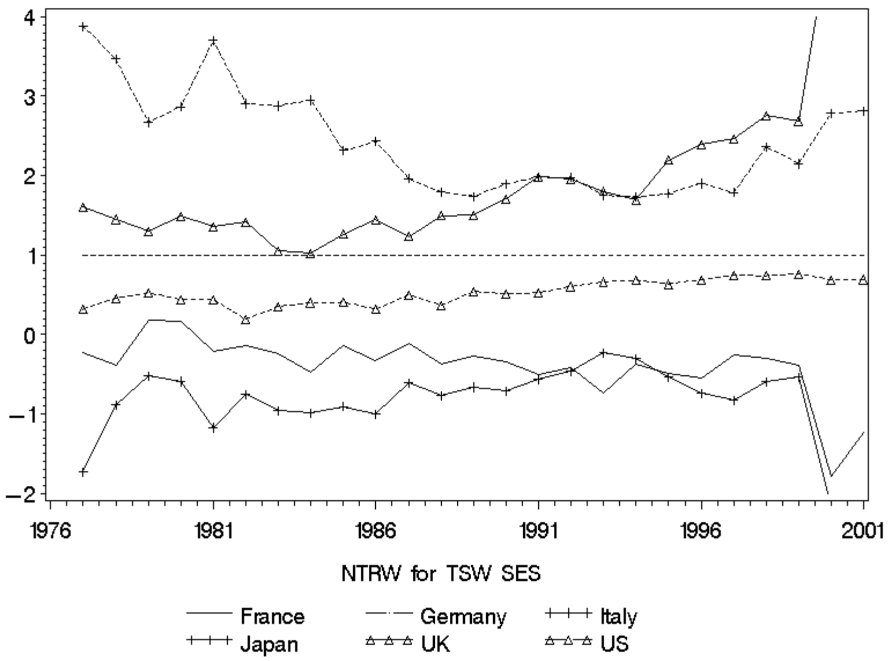

Figure B.12 Non-tropical Roundwood and Tropical Sawnwood substitution, measured by McFadden's shadow elasticity of substitution.

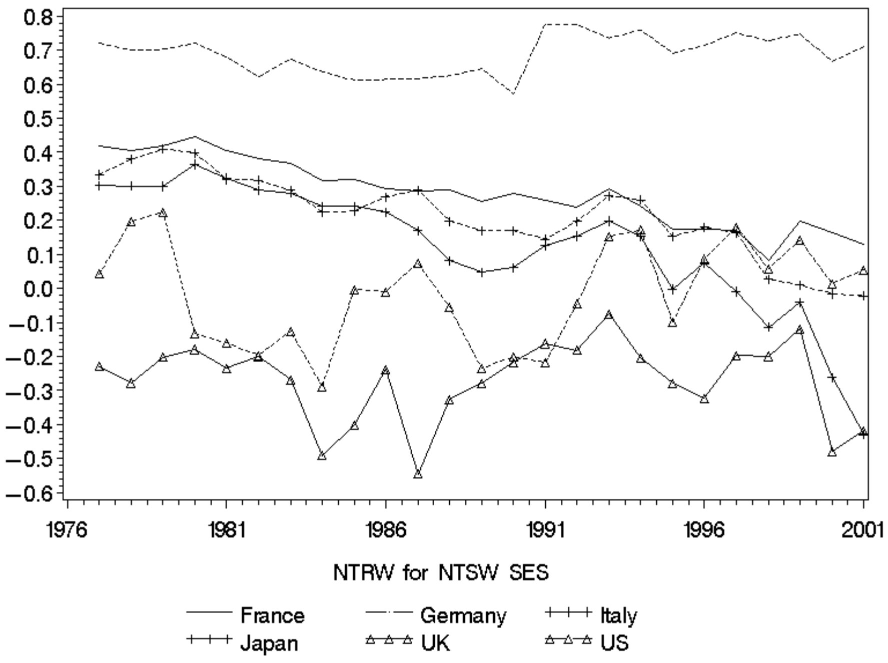

Figure B.13 Non-tropical Roundwood and Non-tropical Sawnwood substitution, measured by McFadden's shadow elasticity of substitution.

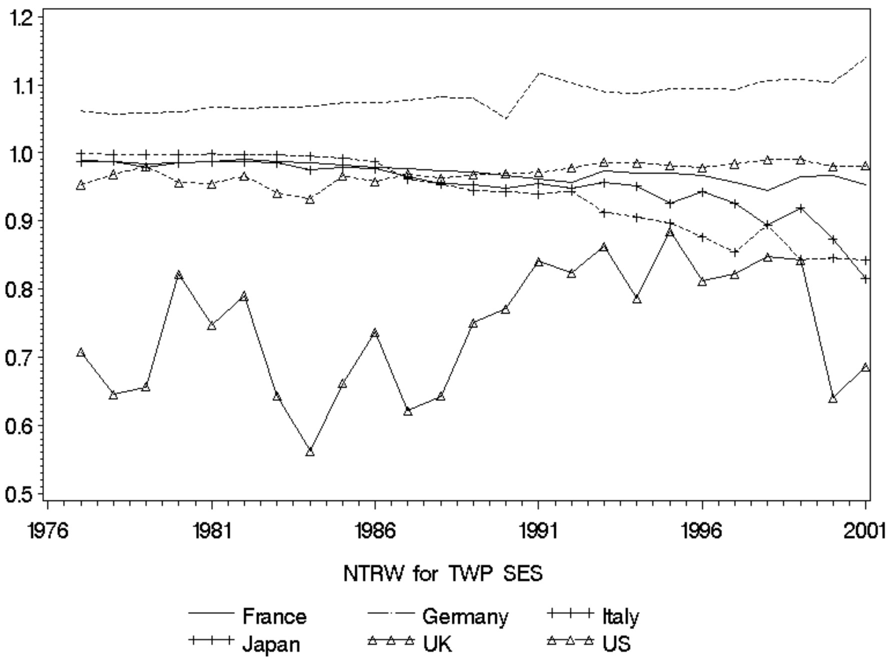

Figure B.14 Non-tropical Roundwood and Tropical Panels substitution, measured by McFadden's shadow elasticity of substitution.

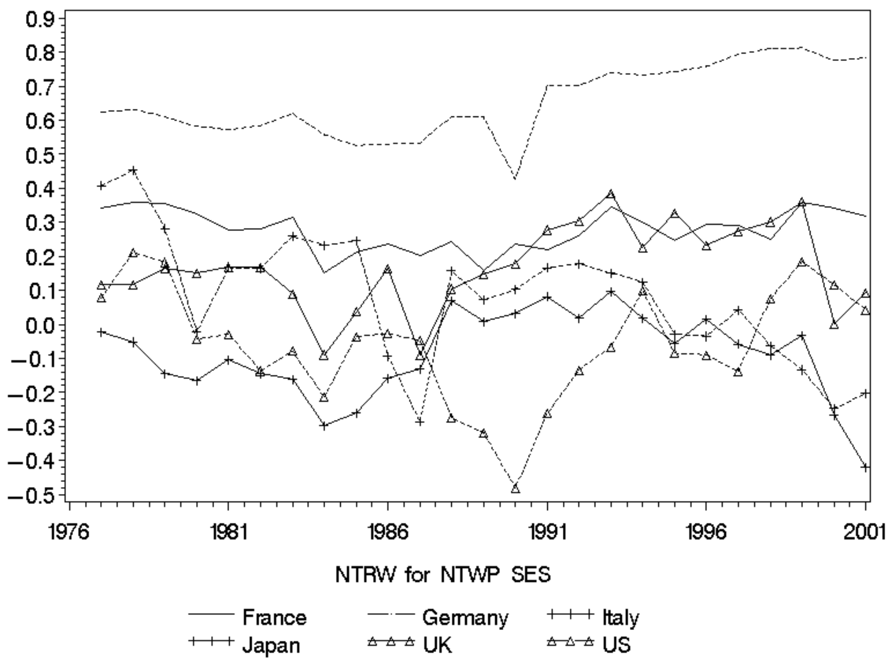

Figure B.15 Non-tropical Roundwood and Non-tropical Panels substitution, measured by McFadden's shadow elasticity of substitution.

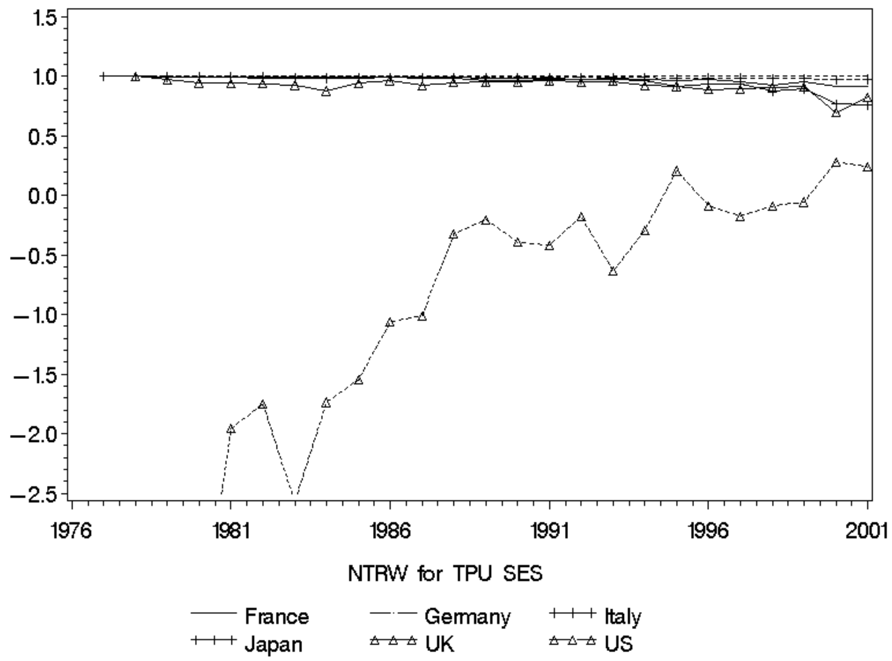

Figure B.16 Non-tropical Roundwood and Tropical Wood Pulp substitution, measured by McFadden's shadow elasticity of substitution.

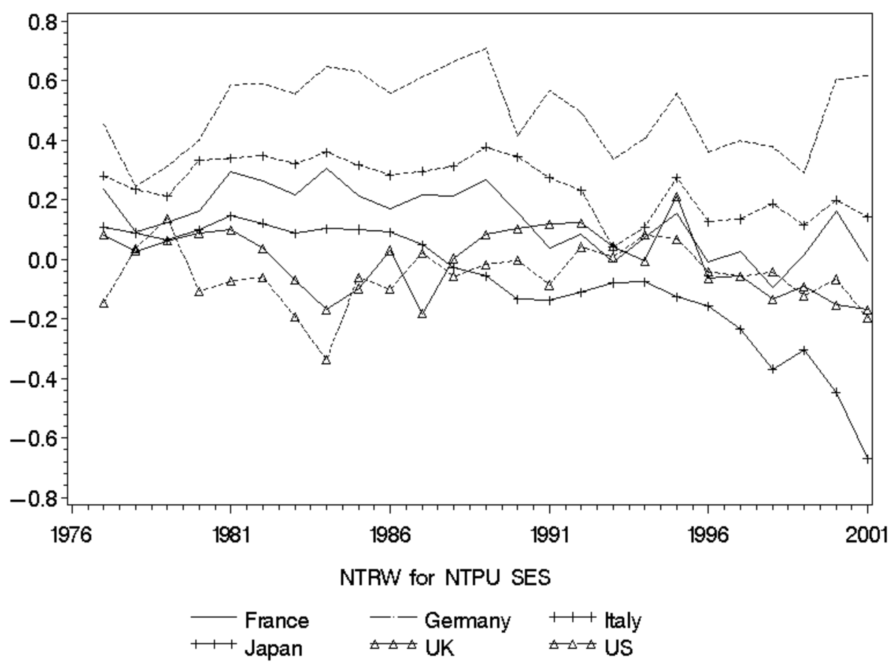

Figure B.17 Non-tropical Roundwood and Non-tropical Wood Pulp substitution, measured by McFadden's shadow elasticity of substitution.

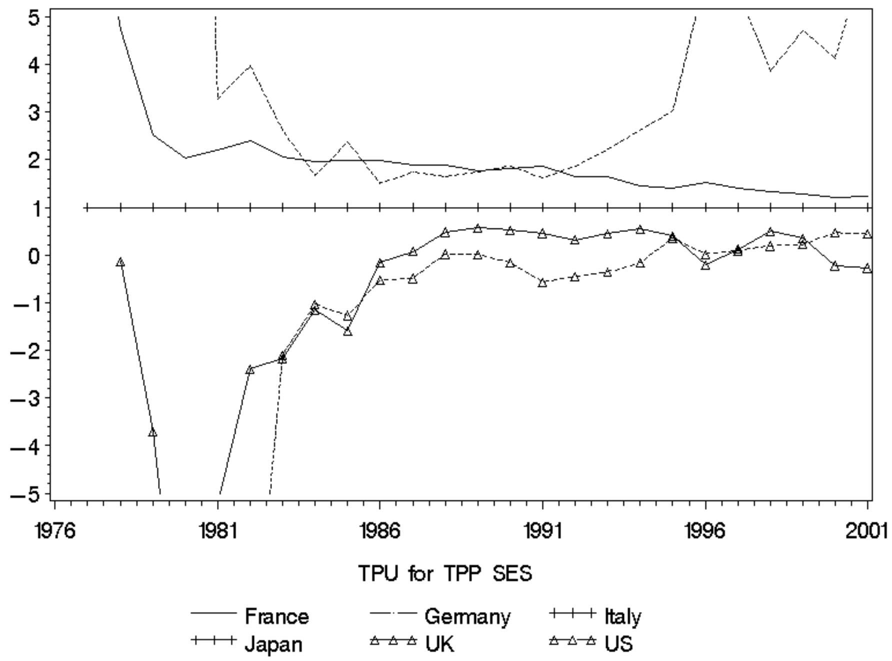

Figure B.18 Tropical Wood Pulp and Tropical Papers substitution, measured by McFadden's shadow elasticity of substitution.

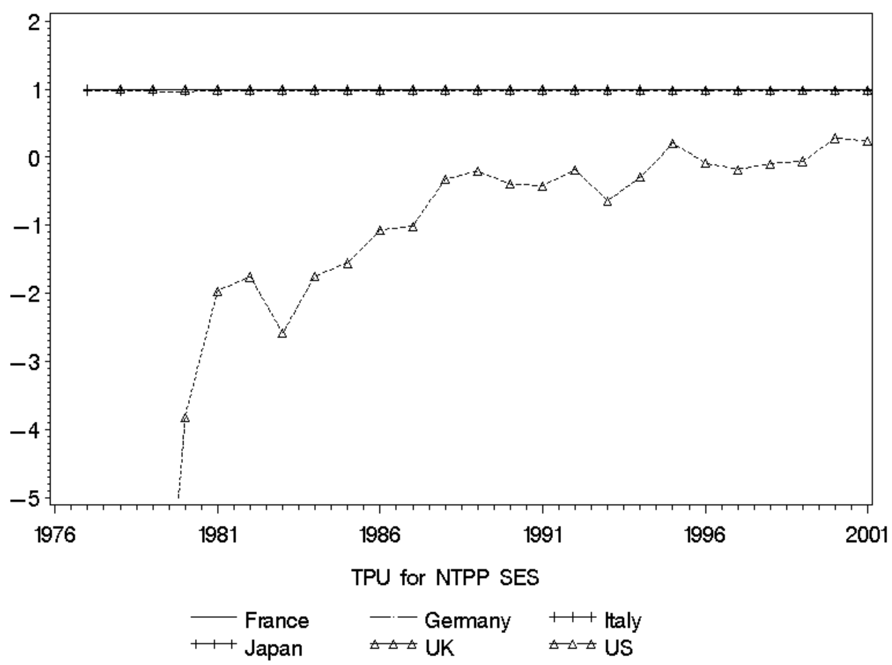

Figure B.19 Tropical Wood Pulp and Non-tropical Papers substitution, measured by McFadden's shadow elasticity of substitution.

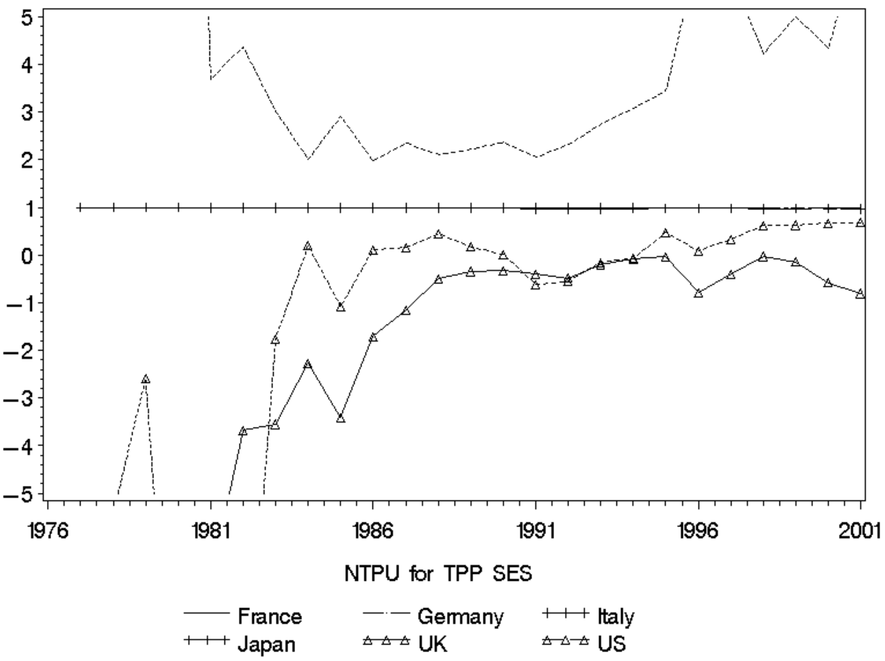

Figure B.20 Non-tropical Wood Pulp and Tropical Papers substitution, measured by McFadden's shadow elasticity of substitution.

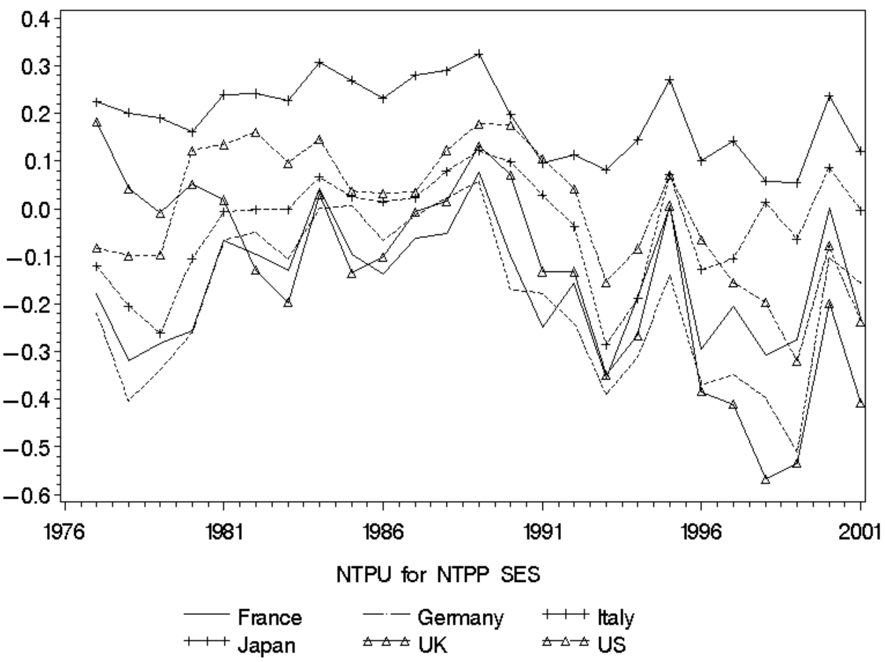

Figure B.21 Non-tropical Wood Pulp and Non-tropical Papers substitution, measured by McFadden's shadow elasticity of substitution.

Appendix C – Data II

Table C.1 provides an overview of the missing and extreme price estimates and how these are adjusted by application of a reference price.

Table C.1 Missing and extreme prices and their adjustments.

Id	Year	Item	Unit price	Ref Id	Adj year	Unit price adj year	Ref unit price 1	Ref unit price 2	Change in %	New unit price
2	1962	TPU	.	4	1963	100,00	193,50	127,30	-0,342	65,79
2	1964	TPU	.	4	1965	121,20	118,10	124,60	0,055	127,87
2	1967	TPU	.	4	1966	108,10	129,00	125,20	-0,029	104,92
2	1969	TPU	.	4	1968	100,00	135,10	135,10	0,000	100,00
2	1973	TPU	.	4	1972	586,10	267,50	175,30	-0,345	384,09
2	1962	TPP	.	4	1973	500,00	178,40	333,30	0,868	934,14
3	1962	TPU	.	4	1974	148,10	124,60	127,30	0,022	151,31
3	1963	TPU	.	4	1974	148,10	124,60	193,50	0,553	229,99
3	1972	TPU	.	4	1975	333,30	175,30	177,40	0,012	337,29
6	1963	TPU	.	4	1965	161,10	118,10	193,50	0,638	263,95
6	1964	TPU	.	4	1965	161,10	118,10	124,60	0,055	169,97
6	1966	TPU	.	4	1968	122,60	129,00	148,10	0,148	140,75
6	1967	TPU	.	4	1968	122,60	129,00	125,20	-0,029	118,99
6	1969	TPU	.	4	1973	194,40	175,30	135,10	-0,229	149,82
6	1970	TPU	.	4	1973	194,40	175,30	135,10	-0,229	149,82
6	1971	TPU	.	4	1973	194,40	175,30	177,80	0,014	197,17
6	1972	TPU	.	4	1973	194,40	175,30	177,40	0,012	196,73
6	1977	TPU	.	4	1978	295,60	295,30	271,30	-0,081	271,58
7	1968	TPU	.	4	1969	156,70	135,10	129,00	-0,045	149,62
7	1970	TPU	.	4	1971	172,50	177,80	135,10	-0,240	131,07
4	1965	TWP	650,00	2	1964	285,70	211,00	222,20	0,053	300,87
4	1966	TWP	648,60	2	1965	300,90	222,20	208,20	-0,063	281,94
4	1967	TWP	1142,90	2	1966	281,90	208,20	229,80	0,104	311,15
5	1962	TWP	275,00	2	1963	168,80	190,10	195,90	0,031	173,95
5	1966	TWP	312,40	2	1965	152,30	222,20	208,20	-0,063	142,70
3	1975	TPP	2305,80	2	1974	730,10	436,10	536,70	0,231	898,52
4	1975	TPP	1600,00	2	1974	364,10	436,10	536,70	0,231	448,09
5	1962	NTPP	641,50	2	1964	184,50	193,70	194,40	0,004	185,17
5	1963	NTPP	641,80	2	1964	184,50	193,70	192,60	-0,006	183,45
5	1967	TPP	877,80	2	1966	188,10	207,50	351,90	0,696	319,00

Legend
Id: 2=France, 3=Germany, 4=Italy, 5=Japan, 6=UK, 7=US
Item: Same abbreviations as Appendix B
Ref: Reference country
Adj: Adjustment
Ref unit price 1: Reference country unit price in the problematic year
Ref unit price 2: Reference country unit price in the adjustment/reference year

Figure C.1 compares a small random sample of EFI-WFSE and FAOSTAT trade data. The United States imports of roundwood and the Italian imports of wood based panels are compared for the period 1962-2002. The figures are import values in million US$, and the figure shows that in case of the US roundwood import the FAOSTAT figures are systematically lower than the EFI-WFSE data and the difference tends to increase over time. In case of the Italian import of panels the two sources are quite close to each other. In both cases the two sources seem to follow the same trends.

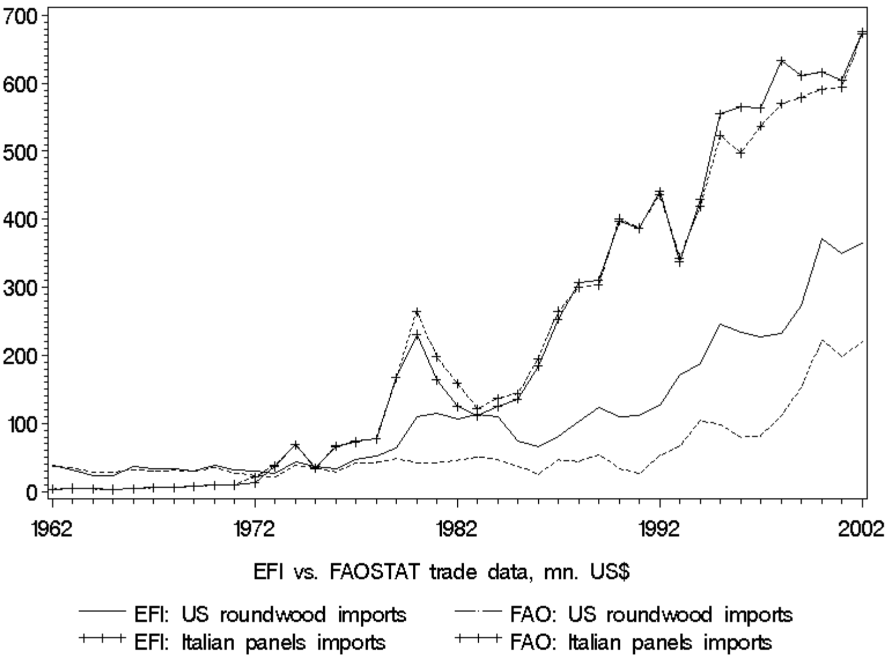

Figure C.1 Comparison of EFI-WFSE and FAOSTAT trade data.

Appendix D – Examples of SAS syntax

This appendix presents examples of the most important parts of the SAS syntax. The following abbreviations are applied:

ds	Difference of the cost share at time t and t-1
d	Difference of the deflated price at time t and t-1
a	Intercept term (Alpha)
g	Parameter (Gamma)
OPE	Own price elasticity
CPE	Cross price elasticity
MES	Morishima's elasticity of substitution
SES	Shadow elasticity of substitution
11	Tropical Roundwood
12	Non-tropical Roundwood
21	Tropical Sawnwood
22	Non-tropical Sawnwood
31	Tropical Panel Products
32	Non-tropical Panel Products
41	Tropical Wood Pulp
42	Non-tropical Wood Pulp
51	Tropical Paper Products
52	Non-tropical Paper Products

Examples:

ds11	Cost share difference for tropical roundwood
a12	intercept term in the equation for non-tropical roundwood
g2121	own-price parameter for tropical sawnwood
g2122	cross-price parameter for tropical and non-tropical sawnwood

… Denotes syntax that has been omitted from the appendix.

Estimation of Translog and elasticities

```
libname regdat 'C:\Documents and
settings\Administrator\Dokumenter\Jan\Speciale\Data\regdat';
run;

libname est3 'C:\Documents and Set-
tings\Administrator\Dokumenter\Jan\speciale\Data\regdat\estimates3';
run;

/*Calculate means of cost shares*/
proc means data=regdat.fr76;
      title 'Means of cost shares';
      var        s11 s12 s21 s22 s31 s32 s41 s42 s51 s52;
run;

options pagesize=60 linesize=72;
```

```
/* TL M3 - homogenous and symmetric model*/
/*Deflated prices - 1st order diffs*/
proc model data=regdat.fr76;
     title 'France: TL M3 - homogenous and symmetric model';
     title2     'LHS and RHS differences, 1977-2001';

/*Parameters*/
endo  ds11 ds12 ds21 ds22 ds31 ds32 ds41 ds42 ds51 /*ds52*/;
exo   d11 d12 d21 d22 d31 d32 d41 d42 d51 d52;
by    id;
parms a11 g1111 g1112 g1121 g1122 g1131 g1132 g1141 g1142 g1151 g1152
      a12       g1212 g1221 g1222 g1231 g1232 g1241 g1242 g1251 g1252
      a21             g2121 g2122 g2131 g2132 g2141 g2142 g2151 g2152
      a22                   g2222 g2231 g2232 g2241 g2242 g2251 g2252
      a31                         g3131 g3132 g3141 g3142 g3151 g3152
      a32                               g3232 g3241 g3242 g3251 g3252
      a41                                     g4141 g4142 g4151 g4152
      a42                                           g4242 g4251 g4252
      a51                                                 g5151 g5152
/*    a52                                                       g5252*/;
restrict
      g1111+g1112+g1121+g1122+g1131+g1132+g1141+g1142+g1151+g1152=0,
      g1112+g1212+g1221+g1222+g1231+g1232+g1241+g1242+g1251+g1252=0,
      g1121+g1221+g2121+g2122+g2131+g2132+g2141+g2142+g2151+g2152=0,
      g1122+g1222+g2122+g2222+g2231+g2232+g2241+g2242+g2251+g2252=0,
      g1131+g1231+g2131+g2231+g3131+g3132+g3141+g3142+g3151+g3152=0,
      g1132+g1232+g2132+g2232+g3132+g3232+g3241+g3242+g3251+g3252=0,
      g1141+g1241+g2141+g2241+g3141+g3241+g4141+g4142+g4151+g4152=0,
      g1142+g1242+g2142+g2242+g3142+g3242+g4142+g4242+g4251+g4252=0,
      g1151+g1251+g2151+g2251+g3151+g3251+g4151+g4251+g5151+g5152=0/*,
      g1152+g1252+g2152+g2252+g3152+g3252+g4152+g4252+g5152+g5252=0*/;

/*Equations*/
      ds11 =    a11 + g1111*d11 + g1112*d12 + g1121*d21 + g1122*d22 +
                g1131*d31 + g1132*d32 + g1141*d41 + g1142*d42 +
                g1151*d51 + g1152*d52;

      ds12 =    a12 + g1112*d11 + g1212*d12 + g1221*d21 + g1222*d22 +
                g1231*d31 + g1232*d32 + g1241*d41 + g1242*d42 +
                g1251*d51 + g1252*d52;

      ds21 =    a21 + g1121*d11 + g1221*d12 + g2121*d21 + g2122*d22 +
                g2131*d31 + g2132*d32 + g2141*d41 + g2142*d42 +
                g2151*d51 + g2152*d52;

      ds22 =    a22 + g1122*d11 + g1222*d12 + g2122*d21 + g2222*d22 +
                g2231*d31 + g2232*d32 + g2241*d41 + g2242*d42 +
                g2251*d51 + g2252*d52;

      ds31 =    a31 + g1131*d11 + g1231*d12 + g2131*d21 + g2231*d22 +
                g3131*d31 + g3132*d32 + g3141*d41 + g3142*d42 +
                g3151*d51 + g3152*d52;

      ds32 =    a32 + g1132*d11 + g1232*d12 + g2132*d21 + g2232*d22 +
                g3132*d31 + g3232*d32 + g3241*d41 + g3242*d42 +
                g3251*d51 + g3252*d52;

      ds41 =    a41 + g1141*d11 + g1241*d12 + g2141*d21 + g2241*d22 +
```

```
                 g3141*d31 + g3241*d32 + g4141*d41 + g4142*d42 +
                 g4151*d51 + g4152*d52;

      ds42 =     a42 + g1142*d11 + g1242*d12 + g2142*d21 + g2242*d22 +
                 g3142*d31 + g3242*d32 + g4142*d41 + g4242*d42 +
                 g4251*d51 + g4252*d52;

      ds51 =     a51 + g1151*d11 + g1251*d12 + g2151*d21 + g2251*d22 +
                 g3151*d31 + g3251*d32 + g4151*d41 + g4251*d42 +
                 g5151*d51 + g5152*d52;

*     ds52 =     a52 + g1152*d11 + g1252*d12 + g2152*d21 + g2252*d22 +
                 g3152*d31 + g3252*d32 + g4152*d41 + g4252*d42 +
                 g5152*d51 + g5252*d52;

fit   ds11 ds12 ds21 ds22 ds31 ds32 ds41 ds42 ds51 /*ds52*/ /
itsur converge=1e-5 maxiter=2000
outsused=est3.frm3shat outest=est3.frm3outest out=est3.frm3out
normal godfrey=5 dw breusch=(d11 d12 d21 d22 d31 d32 d41 d42 d51 d52);

/*Estimate elasticities, insignificant parameter estimates are set to
zero, cost share means are applied*/
estimate
      'OPE1111' ((1/0.0148924)*(g1111+0.0148924**2-0.0148924)),
      ...
      'OPE5252' ((1/0.4373279)*(g5252+0.4373279**2-0.4373279)),
      'CPE1112' ((g1112/0.0148924)+0.1540126),
      ...
      'CPE5251' ((0/0.4373279)+0.000934798),
      'MES1112' (g1112/0.0148924)-(g1212/0.1540126)+1,
      ...
      'MES5251' (0/0.4373279)-(0/0.000934798)+1,
      'SES1112' (0.0148924/(0.0148924+0.1540126))*((g1112/0.0148924)-
           (g1212/0.1540126)+1)+(0.1540126/(0.0148924+0.1540126))*
           ((g1112/0.1540126)-(g1111/0.0148924)+1),
      ...
      'SES5152' (0.000934798/(0.000934798+0.4373279))*((0/0.000934798)-
           (g5252/0.4373279)+1)+(0.4373279/(0.000934798+0.4373279))*
           ((0/0.4373279)-(0/0.000934798)+1);
run; quit;

/*Estimate W*/
proc iml;
      start;
      use est3.frm3shat;
      read all var
      {ds11 ds12 ds21 ds22 ds31 ds32 ds41 ds42 ds52} into s3;
      print s3;
      s3=s3*15/25; /*(T-K)/T*/
      dets3=det(s3);
      logdets3=log(dets3);
      print dets3 logdets3;
      create est3.frm3dets var {logdets3};
      append;
      finish;
run; quit;

/*Test of symmetric restriction*/
data est3.fr_test23;
```

```
      title 'F-test of symmetric restriction';
      set est3.frm2dets;
      set est3.frm3dets;
      N=9;  /*no. of equations*/
      H=11; /*no. of explanatory variables*/
      T=25; /*no. of used observations*/
      K=10; /*no. of parameters in equations*/
      U=exp(logdets2-logdets3);
      testval=((1-U)/U)*((T-H+1-N)/N);
      p=1-probf(testval,N,(T-H+1-N));
proc print;
      var testval p;
run;

/*Test of indedependency of residuals*/
proc reg data=est3.frm3out;
      title 'France: TL M3 test of independency of residuals';
      model ds11 ds12 ds21 ds22 ds31 ds32 ds41 ds42 ds51 = d11 d12 d21
d22 d31 d32 d41 d42 d51 d52;
run; quit;
```

CUSUM/CUSUMSQ tests

```
/*Test for parameter stability*/
/*ds11*/
proc autoreg data=regdat.fr76;
      model       ds11 = d11 d12 d21 d22 d31 d32 d41 d42 d51 d52;
      restrict    d11+d12+d21+d22+d31+d32+d41+d42+d51+d52=0;
      output      out=est3.frcu11
                  recres=rr cusum=c cusumlb=cl cusumub=cu
                  cusumsq=cs cusumsqlb=csl cusumsqub=csu;
run; quit;

...

/*ds52*/
proc autoreg data=regdat.fr76;
      model       ds52 = d11 d12 d21 d22 d31 d32 d41 d42 d51 d52;
      restrict    d11+d12+d21+d22+d31+d32+d41+d42+d51+d52=0;
      output      out=est3.frcu52
                  recres=rr cusum=c cusumlb=cl cusumub=cu
                  cusumsq=cs cusumsqlb=csl cusumsqub=csu;
run; quit;

/*CUSUM + CUSUMSQ test*/
/*ds11*/
data est3.frctest11 (keep=id year c);
      set   est3.frcu11;
      if    c<cl or c>cu then output;
run;

proc print data=est3.frctest11;
      title 'ds11-CUSUM';
run;

data est3.frcstest11 (keep=id year cs);
```

```
     set   est3.frcu11;
     if    cs<csl or cs>csu then output;
run;

proc print data=est3.frcstest11;
     title 'ds11 - CUSUMSQ';
run;

...

/*ds52*/
data est3.frctest52 (keep=id year c);
     set   est3.frcu52;
     if    c<cl or c>cu then output;
run;

proc print data=est3.frctest52;
     title 'ds52 - CUSUM';
run;

data est3.frcstest52 (keep=id year cs);
     set   est3.frcu52;
     if    cs<csl or cs>csu then output;
run;

proc print data=est3.frcstest52;
     title 'ds52 - CUSUMSQ';
run;
```

Compute elasticities over time

```
/*Parameters for elasticities, insignificant parameters are set to
zero*/
data regdat.frsubparms(keep=id    g1111 g1112 g1121 g1122 g1131 g1132
                                  g1141 g1142
                                  g1212 g1221 g1222 g1231 g1232
                                  g1241 g1242
                                  g2121 g2122
                                  g2222
                                  g3131 g3132
                                  g3232
                                  g4141 g4142 g4151 g4152
                                  g4242 g4251 g4252
                                  g5151 g5152
                                  g5252);
     set   est3.frm3outest;
     g1121=0; g1122=0; g1131=0; g1132=0;
     g1221=0; g1222=0; g1231=0; g1232=0; g1241=0; g1242=0;
     g3131=0; g3132=0;
     g4141=0; g4142=0; g4152=0;
     g4251=0;
     g5151=0; g5152=0;
     g5252=0.203842;
run;

/*Export subparms (one obs) to Excel and reimport as subparms2 with
year var and 25 obs*/
```

```
/*Calculate MES and SES*/
data regdat.frsub(keep=id year    mes1112 mes1211 ses1112
                                  mes1121 mes2111 ses1121
                                  mes1122 mes2211 ses1122
                                  mes1131 mes3111 ses1131
                                  mes1132 mes3211 ses1132
                                  mes1141 mes4111 ses1141
                                  mes1142 mes4211 ses1142
                                  mes1221 mes2112 ses1221
                                  mes1222 mes2212 ses1222
                                  mes1231 mes3112 ses1231
                                  mes1232 mes3212 ses1232
                                  mes1241 mes4112 ses1241
                                  mes1242 mes4212 ses1242
                                  mes2122 mes2221 ses2122
                                  mes3132 mes3231 ses3132
                                  mes4142 mes4241 ses4142
                                  mes4151 mes5141 ses4151
                                  mes4152 mes5241 ses4152
                                  mes4251 mes5142 ses4251
                                  mes4252 mes5242 ses4252
                                  mes5152 mes5251 ses5152);
     set   regdat.frsubparms2;
     set   regdat.fr76;
     mes1112=(g1112/s11)-(g1212/s12)+1;
     mes1211=(g1112/s12)-(g1111/s11)+1;
     ses1112=((s11/(s11+s12))*mes1112)+((s12/(s11+s12))*mes1211);
     ...
     mes5152=(g5152/s51)-(g5252/s52)+1;
     mes5251=(g5152/s52)-(g5151/s51)+1;
     ses5152=((s51/(s51+s52))*mes5152)+((s52/(s51+s52))*mes5251);
run;
```

Appendix E – Examples of SAS output

```
                         Means of cost shares                    1
                                    10:17 Thursday, September 16, 2004

                         The MEANS Procedure
Variable N        Mean         Std Dev         Minimum         Maximum
----------------------------------------------------------------------

s11      25     0.0148924     0.0067060     0.000990753       0.0276492
...
s52      25     0.4373279     0.0496368     0.3389436         0.5125887
----------------------------------------------------------------------

             France: TL M3 - homogenous and symmetric model         2
                   LHS and RHS differences, 1977-2001
                                    10:17 Thursday, September 16, 2004

                          The MODEL Procedure
                             Model Summary

                      Model Variables         19
                      Endogenous               9
                      Exogenous               10
                      Parameters              63
                      Equations                9
                      Number of Statements   127
NOTE: The parameter g1112 is shared by 2 of the equations to be
      estimated.
...
NOTE: The parameter g4251 is shared by 2 of the equations to be
      estimated.

                      The 9 Equations to Estimate

 ds11 =  F(a11(1), g1111(d11), g1112(d12), g1121(d21),
         g1122(d22), g1131(d31), g1132(d32), g1141(d41),
         g1142(d42), g1151(d51), g1152(d52))
...
 ds51 =  F(g1151(d11), g1251(d12), g2151(d21), g2251(d22),
         g3151(d31), g3251(d32), g4151(d41), g4251(d42),
         a51(1), g5151(d51), g5152(d52))

                          The MODEL Procedure
                            ITSUR Estimation

    NOTE: At ITSUR Iteration 23 CONVERGE=0.00001 Criteria Met.

                            Data Set Options

                      DATA=        REGDAT.FR76
                      OUT=         EST3.FRM3OUT
                      OUTEST=      EST3.FRM3OUTEST
                      OUTSUSED=    EST3.FRM3SHAT

                         Minimization Summary

                   Parameters Estimated          54
                   Method                     Gauss
```

```
              Iterations                    23

                 Final Convergence Criteria

                 R                    6.279E-6
                 PPC(g4251)           0.000066
                 RPC(g4251)           0.000066
                 Object                1.1E-15
                 Trace(S)             0.000209
                 Objective Value          6.48
                 S                           0

                    Observations Processed

                        Read       25
                        Solved     25

         Nonlinear ITSUR Summary of Residual Errors

                 DF      DF
Equation        Model   Error       SSE         MSE    Root MSE   R-Square

ds11              6      19    0.000075    3.943E-6    0.00199     0.6423
...
ds51              6      19    4.483E-6     2.36E-7   0.000486     0.4961

                   Nonlinear ITSUR Summary
                     of Residual Errors

                              Adj      Durbin
              Equation        R-Sq     Watson

              ds11           0.5481     1.9238
            ...
              ds51           0.3635     2.1148


             Nonlinear ITSUR Parameter Estimates

                         Approx             Approx
 Parameter    Estimate   Std Err t Value   Pr > |t| Label

 a11          -0.00073 0.000421    -1.74     0.0986
 g1111        0.016837  0.00205     8.20     <.0001
 g1112        -0.00938  0.00338    -2.78     0.0120
 g1121        0.003362  0.00203     1.66     0.1135
 g1122        -0.00171  0.00397    -0.43     0.6711
 g1131        -0.00131 0.000938    -1.40     0.1778
 g1132        -0.00084  0.00435    -0.19     0.8490
 g1141        -0.00542 0.000880    -6.16     <.0001
 g1142        0.008495  0.00231     3.68     0.0016
 g1151        0.002628 0.000709     3.71     0.0015
 g1152        -0.01266  0.00603    -2.10     0.0492
 a12          -0.00314  0.00152    -2.07     0.0524
 ...
 a51          0.000159 0.000107     1.50     0.1512
 g5151        -0.00017 0.000660    -0.26     0.7976
 g5152        -0.00258  0.00203    -1.27     0.2182
```

```
 Restrict0    30.12515  38.5358    0.78     0.4493 g1111+g1112+g1121+
                                                   g1122+g1131+g1132+
                                                   g1141+g1142+g1151+
                                                   g1152=0
...
 Restrict8    38.11561  69.8052    0.55     0.5987 g1151+g1251+g2151+
                                                   g2251+g3151+g3251+
                                                   g4151+g4251+g5151+
                                                   g5152=0

 OPE1111      0.145494   0.1380    1.05     0.3048 ((1/0.0148924)*(
                                                   g1111+0.0148924**
                                                   2-0.0148924))
...
 OPE5252      -0.09656   0.0862   -1.12     0.2767 ((1/0.4373279)*(
                                                   g5252+0.4373279**
                                                   2-0.4373279))
 CPE1112      -0.47561   0.2267   -2.10     0.0496 52'
                                                   ((1/0.4373279)*(
                                                   g5252+0.4373279**
                                                   2-0.4373279))
...
 CPE5251      0.000935        0     .         .    ((g4252/0.4373279)+
                                                   0.1285200)
 MES1112      -0.27304   0.2464   -1.11     0.2817 ((0/0.4373279)+
                                                   0.000934798)
...
 MES5251             1        0     .         .    (0/0.000934798)-(
                                                   g4242/0.1285200)+1
 SES1112      -0.19867   0.1383   -1.44     0.1671 52'
                                                   (0/0.000934798)-(
                                                   g5252/0.4373279)+1
...
 SES5152      0.999006 0.000184 5432.46     <.0001 (0.000934798/(0.
                                                   000934798+0.4373279)
                                                   )*((0/0.000934798)-(
                                                   g5252/0.4373279)+1)+
                                                   (0.4373279/(0.
                                                   000934798+0.4373279)
                                                   )*((0/0.4373279)-(
                                                   0/0.000934798)+1)

           Number of Observations     Statistics for System

           Used                25    Objective         6.4800
           Missing              0    Objective*N     162.0000

                        Heteroscedasticity Test

 Equation        Test               Statistic     DF    Pr > ChiSq

 ds11            Breusch-Pagan          10.89     10        0.3662
...
 ds51            Breusch-Pagan           8.14     10        0.6152


                   Godfrey's Serial Correlation Test

            Equation        Alternative       LM    Pr > LM
```

```
       ds11              1             10.80     0.0010
                         2             12.65     0.0018
                         3             13.68     0.0034
                         4             14.04     0.0072
                         5             18.67     0.0022
       ds12              1             12.83     0.0003
...
       ds51              1              8.48     0.0036
                         2              9.42     0.0090
                         3             10.83     0.0127
                         4             10.83     0.0285
                         5             12.06     0.0339


                           Normality Test
     Equation        Test Statistic       Value       Prob

     ds11            Shapiro-Wilk W        0.94     0.1632
   ...
     ds51            Shapiro-Wilk W        0.96     0.5261
     System          Mardia Skewness      184.9     0.1381
                     Mardia Kurtosis      -0.79     0.4320
                     Henze-Zirkler T       0.30     0.7611

                F-test of symmetric restriction
                  Obs       testval       p

                   1     .003110109    1.00000
```

```
France: TL M3 test of independency of residuals

The REG Procedure
Model: MODEL1
Dependent Variable: ds11

Analysis of Variance

                               Sum of          Mean
Source              DF        Squares        Square   F Value   Pr > F

Model               10     0.00003159    0.00000316      1.02   0.4735
Error               14     0.00004334    0.00000310
Corrected Total     24     0.00007493


        Root MSE              0.00176    R-Square     0.4216
        Dependent Mean    -3.1225E-19    Adj R-Sq     0.0084
        Coeff Var         -5.63482E17


Parameter Estimates

                        Parameter       Standard
Variable      DF         Estimate          Error    t Value    Pr > |t|

Intercept      1       0.00006665     0.00038928       0.17      0.8665
d11            1         -0.00207        0.00296      -0.70      0.4972
...
d52            1         -0.10609        0.06349      -1.67      0.1170

...

Dependent Variable: ds51

Analysis of Variance

...

Parameter Estimates

                        Parameter       Standard
Variable      DF         Estimate          Error    t Value    Pr > |t|

Intercept      1       0.00003448     0.00010917       0.32      0.7568
d11            1      -0.00040304     0.00083120      -0.48      0.6353
...
d52            1         -0.00550        0.01781      -0.31      0.7620
```

Appendix F – Literature search strategy

Literature on wood products and substitution was searched for in the article databases AGRICOLA, AGRIS and CAB Abstracts, which are available through the campus library. AGRICOLA is produced by the United States National Agricultural Library. AGRIS is a FAO products and CAB Abstracts is a product of Centre for Agriculture and Biosciences, England. The search engine was WebSPIRS 5 accessed on the Internet. Literature on the elasticity of substitution in general was searched for by the JStore publications database at the Copenhagen Business School.

The following presents the search history. The number of records refers to the CAB Abstracts search, which returned most articles.

#12 (((explode "demand-elasticities" in SU) or
(explode "demand-functions" in SU)) or
(explode "econometric-models" in SU)) and
((explode "forest-products" in SU) or
(explode "wood-products" in SU))
(17 records)

#11 ((explode "demand-elasticities" in SU) or
(explode "demand-functions" in SU)) or
(explode "econometric-models" in SU)
(1910 records)

#10 (explode "forest-products" in SU) or
(explode "wood-products" in SU)
(23737 records)

#9 (explode "demand-elasticities" in SU) or
(explode "demand-functions" in SU)
(791 records)

#8 explode "econometric-models" in SU
(1154 records)

#7 explode "forest-products" in SU
(18862 records)

#6 explode "wood-products" in SU
(6642 records)

#5 cost share
(100 records)

#4 demand system
(388 records)

#3 econometric model
(1132 records)

#2 forest product
(468 records)

#1 wood product
(169 records)

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